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AN AIR FORCE GUIDE TO THE SYSTEM SPECIFICATION

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2500 Colorado Avenue
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This report addresses procedures, objectives, and typical problems associated with development and uses of the system specification. It is one of a series of guidebooks written to assist members of Air Force Systems Command program offices in managing software aspects of military system acquisitions. Widespread problems with software in systems have been found to result most often from inadequate early management planning and definition of technical requirements. Initial portions of this guidebook describe the general sequence, nature, and levels of system engineering studies that are

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) needed during conceptual and "validation" phases of a system program to develop adequately-documented requirements that can provide the essential technical basis for sound management plans and decisions to initiate system full-scale development. Related topics include: current problems and questions associated with recognized functions of the system specification in relation to other types of specifications; software as a factor in program risks; principles of specification preparation; and prominent questions about the handling of requirements affecting software.

PREFACE

This guide is one of a series of Software Acquisition Management (SAM) guidebooks which have been developed under sponsorship of the Electronic Systems Division (ESD) of the Air Force Systems Command. The intent of the series as a whole is to provide guidance information, supplementing and explaining formal requirements set forth in official documents associated with the 800-series Air Force regulations, to assist program office personnel in managing software aspects of military system acquisitions.

Air Force management of the SAM guidebook series is provided by ESD's Directorate of Computer Systems Engineering (ESD/TOI). This guidebook has been prepared under ESD Contract No. F19628-79-C-0186 with the System Development Corporation (SDC), Santa Monica, California, through subcontract with the Planning Analysis Research Institute (PARI), which is also located in Santa Monica. The principal investigator for this task is the guidebook author, Dr. Lloyd V. Searle, of PARI. The contract manager representing SDC is Marcia C. Finfer. Administrative guidance, review, and coordination were accomplished by the project manager for ESD/TOI, Mr. John Mott-Smith.

The author is indebted to the following people for contributing suggestions and materials which proved to be particularly useful during the development of this guidebook:

- Mr. Ernest Wade, of the Aerospace Corporation, for use of materials which he had developed previously for guidance in preparing specifications for space systems.

- Mr. Charles I. Silverstein, of SDC (Denver, Colorado), for comments and suggestions pertaining to problem areas associated with the management of commercial items in system programs.

- Mr. Robert D. Marshall, of SDC (Sunnyvale, California), for providing samples of functional flow block diagrams applicable to electronic system information processing functions.

The SAM guidebook series consists of individual documents which have been issued, as they were completed, in the form of ESD technical reports. Following is a complete list of guidebooks issued previously in the series, together with their National Technical Information Service (NTIS) or Defense Documentation Center (DDC) accession numbers:

	DDC/NTIS Accession No.
ESD-TR-75-85, An Air Force Guide For Monitoring and Reporting Software Development Status, September 75	AD-A016488
ESD-TR-75-365, An Air Force Guide to Contracting for Software Acquisition, January 76	AD-A020444
ESD-TR-76-159, An Air Force Guide To Software Documentation Requirements, June 76	AD-A027051
ESD-TR-77-16, Software Acquisition Management Guidebook: Statement of Work Preparation, January 77	AD-A035924
ESD-TR-77-22, Software Acquisition Management Guidebook: Life Cycle Events, February 77	AD-A037115
ESD-TR-77-130, Software Acquisition Management Guidebook: Software Development and Maintenance Facilities, April 77	AD-A038234
ESD-TR-77-254, An Air Force Guide to Computer Program Configuration Management, August 77	AD-A047308
ESD-TR-77-255, Software Acquisition Management Guidebook: Software Quality Assurance, August 77	AD-A047318
ESD-TR-77-263, Software Acquisition Management Guidebook: Verification, August 77	AD-A048577
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ESD-TR-78-117, Software Acquisition Management Guidebook: Reviews and Audits, November 77	AD-A052567
ESD-TR-78-139, An Air Force Guide to the Computer Program Development Specification, November 77	AD-A055573
ESD-TR-78-140, Software Acquisition Management Guidebook: Software Cost Estimation and Measurement, March 78	AD-A055574
ESD-TR-78-141, Software Acquisition Management Guidebook: Series Overview, March 78	AD-A055575
ESD-TR-78-178, Software Acquisition Management Guidebook: Regulations, Specifications, and Standards, November 78	AD-A061793

TABLE OF CONTENTS

Page

PREFACE 1

SECTION 1. INTRODUCTION 5

SECTION 2. MODEL CONCEPTS 9

2.1 Phasing Considerations - General 10

2.2 The System Engineering Process 13

2.3 Generation of the System Concept 17

2.3.1 Initial System Concept 17
2.3.2 Operational Requirements Analysis 18
2.3.3 Design Studies 21

2.4 The Initial System Specification 23

2.4.1 System Engineering Analysis 23
2.4.2 Preparation of the Specification 36

2.5 Completing the System Specification - Validation Phase . . 38

2.5.1 Planning and Preparation 39
2.5.2 Implementation 41
2.5.2.1 System Definition 41
2.5.2.2 Configuration Item Definition 44
2.5.3 Evaluation and Decision 48

SECTION 3. ISSUES AND PROBLEM AREAS 51

3.1 Summary of System Specification Functions 51

3.1.1 Relations of Technical to Management Factors 52
3.1.2 Summary of Functions 55

3.2 Trends, and Questions to be Explored 60

3.2.1 Illustrative Problem Case 61
3.2.2 Proposed Solutions 64

3.3 Program Risks 68

APPENDIX A. SYSTEM SPECIFICATION PREPARATION 73

APPENDIX B. SAMPLE PARAGRAPH 3.3.8 105

APPENDIX C. SAMPLE FUNCTIONAL FLOW BLOCK DIAGRAMS 113

APPENDIX D. REFERENCES 121

APPENDIX E. ABBREVIATIONS 123

ILLUSTRATIONS

Figure		Page
2-1	Phasing of System Specification Development	11
2-2	Generalized Elements of the System Engineering Process	15
2-3	Overview of Conceptual Phase Analysis	24
2-4	Flow of Major Technical Tasks - Conceptual Phase	26
2-5	Outline of Validation Phase - Implementation Period	42
3-1	Specification Tree	54
3-2	Generation Breakdown (Assembly Tree; Installation Tree)	54
3-3	Summary of System Specification Coverage and Functions	57
3-4	Sample Arrangement of Major Equipment Items in a System Segment	62
A-1	Content Outline for the System Specification	75
C-1	Logic Notations	114
C-2	Top-Level Functional Flow Block Diagram	115
C-3	First-Level Functional Flow Block Diagram	116
C-4	Second-Level Functional Flow Block Diagram	117
C-5	Third-Level Functional Flow Block Diagram	118
C-6	Fourth-Level Functional Flow Block Diagram	119

SECTION 1. INTRODUCTION

A general aim of the Software Acquisition Management (SAM) guidebook series is to help promote more effective acquisition of software elements in military systems. Most of the guidebooks published to date in the series have been devoted to selected aspects of software development and support, as such, in relation to management concepts which apply in the context of system acquisition programs. That general focus is significant, since a working knowledge of those special concepts and procedures is critical to the successful acquisition of software/computer resources in that context.

This guidebook differs from others of the series in that its topic relates somewhat more directly to the system as a whole than to a system's software elements. However, integration of software with systems is a two-way process. While most of the effort may be pointed properly towards adapting "software management" to the system program environment, there is a growing recognition that the prominence of software--particularly in ground electronic systems--also has implications for management at the system level. The system specification (the Type A specification as defined in MIL-S-83490) was chosen as the topic of this guidebook largely because it is the designated source of basic *requirements* for the system software functions and performance, and because many of the problems associated with software acquisition in systems have been traceable to inadequacies in those basic requirements.

The material contained in this guidebook is addressed primarily to members of system Program Offices (POs) who are responsible for software aspects of system programs, and in part to personnel of supporting contractors--although the guidebook is not intended and should not be used as a contractual document. If improvements are to occur, those are the people who must have a common understanding of the system specification development and functions. At the same time, it is recognized that a PO's approach to the system specification is constrained by basic program management policies that are determined, for each program, at or above the Program Manager level; hence, the discussions also touch on certain areas which appear to merit attention by those higher-level managers.

The organization and content of material presented in following sections and appendices of this guidebook are summarized below.

Section 2, Model Concepts, is devoted to a description of the system specification development process. Emphasis is placed on describing the levels and nature of system engineering studies which are normally *needed*--i.e., not necessarily typical in practice--to develop comprehensive requirements information in areas that are significant to system data processing functions and performance. One objective of this section is to outline the manner in which the technical process can be planned and managed systematically within the framework of program management policies and milestones established in such current documents as AFR 800-2 and AFR 57-1. Key elements of coverage include the following:

a. Levels of system engineering studies are described ranging from derivation of operational requirements through functional analysis, advanced development, and trade studies leading to system/system segment design.

b. Levels and objectives of the technical steps are related to: phasing of the system program, from issuance of a Statement of Operational Need (SON) through conceptual and validation phases; identified roles of Government agencies and contractors; and key areas of the system specification content affecting computer resources.

c. Technically, the focus of discussion is on *system* engineering, which is characterized by concern with functional analysis and design at the system level. However, the description also identifies activities at various stages of the overall process which require significant support by specialists in software engineering.

Section 3, Issues and Problem Areas, identifies selected areas in which problems have been encountered pertaining to development and uses of the system specification in electronic system programs. This section includes discussions of the following topics:

a. Intended functions of the system specification in a model system program, in relation to functions of other specification types. In established policy and practice, the system specification has some, but limited, uses as a contractual compliance document. Basically, equipment and computer program elements of a system are acquired most directly against lower-level (configuration item) specifications.

b. Current problems associated with PO manpower and increasing prominence of commercial components. This discussion outlines some novel uses of the system specification which have been employed or suggested to alleviate difficulties being experienced in recent system programs.

c. Factors of risk. In general, "program risks" involve deficiencies of either a technical or management nature, or both. This discussion suggests that: few if any system program failures have been known to result from software technical limitations as such; the serious troubles encountered in actual practice have typically been matters of (1) inadequate definitions of *requirements*, via system engineering effort, and (2) inadequate program planning and management. These factors point to a general need for wider use of the validation phase as a device for reducing those prominent risks.

Appendix A, System Specification Preparation, is provided herein as a preliminary basis for further development of guidance pertaining to preparation of the system specification in accordance with format and content instructions contained in Appendix I of MIL-STD-490. A complete guide to interpret those instructions comprehensively for electronic systems is needed but is not yet available. Although clearly in line with this guidebook's title and objectives, the adequate development of such guidance will require a longer-term effort. As a sample approach, however, Appendix A presents portions of a guide which was prepared at The Aerospace Corporation for space systems, together with supplementary comments on a few of the paragraphs considered to be of particular importance to software/computer resources. Portions covered in the sample are confined to Section 3, Requirements, of the system specification.

Appendix B, Sample Paragraph 3.3.8, contains a sample of system specification content dealing with design and construction standards for computer programs which has been developed at ESD and proposed for general use. The appendix includes comments by this guidebook author on suitability of the proposed sample in relation to proper content and functions of the system specification. Overall, this paragraph deserves more careful and sparing treatment than it has generally received.

Appendix C, Sample Functional Flow Block Diagrams, presents examples of functional flow diagrams prepared for system data processing functions, based on format/content instructions contained in DI-S-3604. These samples illustrate one prominent form of system engineering documentation discussed in the preceding Section 2 (Model Concepts), which should normally be included as a part of the information furnished in paragraph 3.1.4 of the system specification.

Appendix D and Appendix E contain lists of the source references and abbreviations, respectively, that are cited and used in the guidebook text.

NOTE TO READERS

Due to widespread conflicts in accepted definitions, use of the term "software" has been systematically avoided in most official Air Force documents dealing with acquisition management, for many years (viz., AFR 800-14, AFR 65-3, MIL-STD-483, MIL-STD-1521A). "Computer program" does have a recognized Air Force definition (e.g., in MIL-STD-483) which is relatively precise and much less subject to diverse interpretations. "Software" is used in this guidebook because it is established as a part of the SAM guidebook series title. However, readers are requested to note that its intended meaning, throughout the text herein, is exactly equivalent to "computer program(s)".

SECTION 2. MODEL CONCEPTS

Air Force policies and guidance for acquisition managment have long been based on the use of a "model" system program as the essential reference framework for managing the development of new systems. The model for a system program consists basically of a predetermined scenario of management actions and events keyed to a standard sequence of system life-cycle phases. It reflects established relationships and responsibilities of implementing/participating organizations and incorporates a spectrum of associated standards and guidance pertaining to objectives, procedures, and criteria affecting the prescribed actions and events.

Actions and events identified in the model include ones for which some requirements are mandatory and others optional, in varying degrees. While the construction and use of such a model assumes that all system programs will have a broad range of common characteristics, it is also recognized that every individual program is likely to depart from the model in some of its aspects. However, the important underlying principle is that of "management by exception"--i.e., by having predetermined solutions for the planning and conduct of major parts of all programs, each Program Manager should have relatively more time and freedom for attention to the special aspects of his individual program.

Thus, the assumption that standards must be "tailored" to the needs of each program is inherent in the model approach, although the widespread recent emphasis which has been placed on the tailoring activity as such has caused many Program Managers to lose sight of the fact that the converse is also true--in that, the model must first be known and observed before it can be sensibly tailored. Considering the complex spectrum of tasks involved in managing the acquisition of any large military system, promising alternatives to the development, continuing refinement, and use of the model approach do not exist.

This section outlines a model approach to developing the system specification for a large electronic system. The approach is described with emphasis on what <u>should</u> occur, in the light of demonstrated technical and management needs of the process, rather than what has been necessarily typical in actual practice. In accordance with purposes of this guidebook, attention is focused on early phases of the life cycle, and on the scope and nature of technical requirements information to be collected, analyzed, and organized as a sound basis for initiating the full-scale development of a complex, computer-based system.

2.1 Phasing Considerations - General

The model adopted for overall phasing of the system specification development is illustrated in Figure 2-1. This model is chosen primarily because it is one which can provide for meeting needs of the technical process, and because it also permits meeting the requirements of many established standards which apply during conceptual and validation phases of system programs. At the same time, it incorporates certain assumptions about electronic system programs which are not explicitly confirmed or emphasized in current top-level policies for major defense systems, nor clearly exemplified in most of the actual practice. Principle points of the diagram to be expanded upon in following sections, including some potential points of issue, are summarized as follows:

a. Development of a large, digital computer-based system *requires full utilization of available system engineering resources, over the maximum available time span*. Significant initial steps in the total process must be accomplished during the preconceptual period, in conjunction with and following initial identification of the operational need.

b. Alternative solutions to meeting mission needs of the operational command are evaluated preceding and during the conceptual phase (by the implementing command), resulting normally in selection of a system design at the level of system segments/functional areas. *The initial system specification includes firm system functional, performance, and interface requirements, and allocations of those to the system segments.* Otherwise, it should provide maximum latitude for alternative design solutions, below the segment level.

c. At that point in time--i.e., at the outset of a validation phase--*the system*

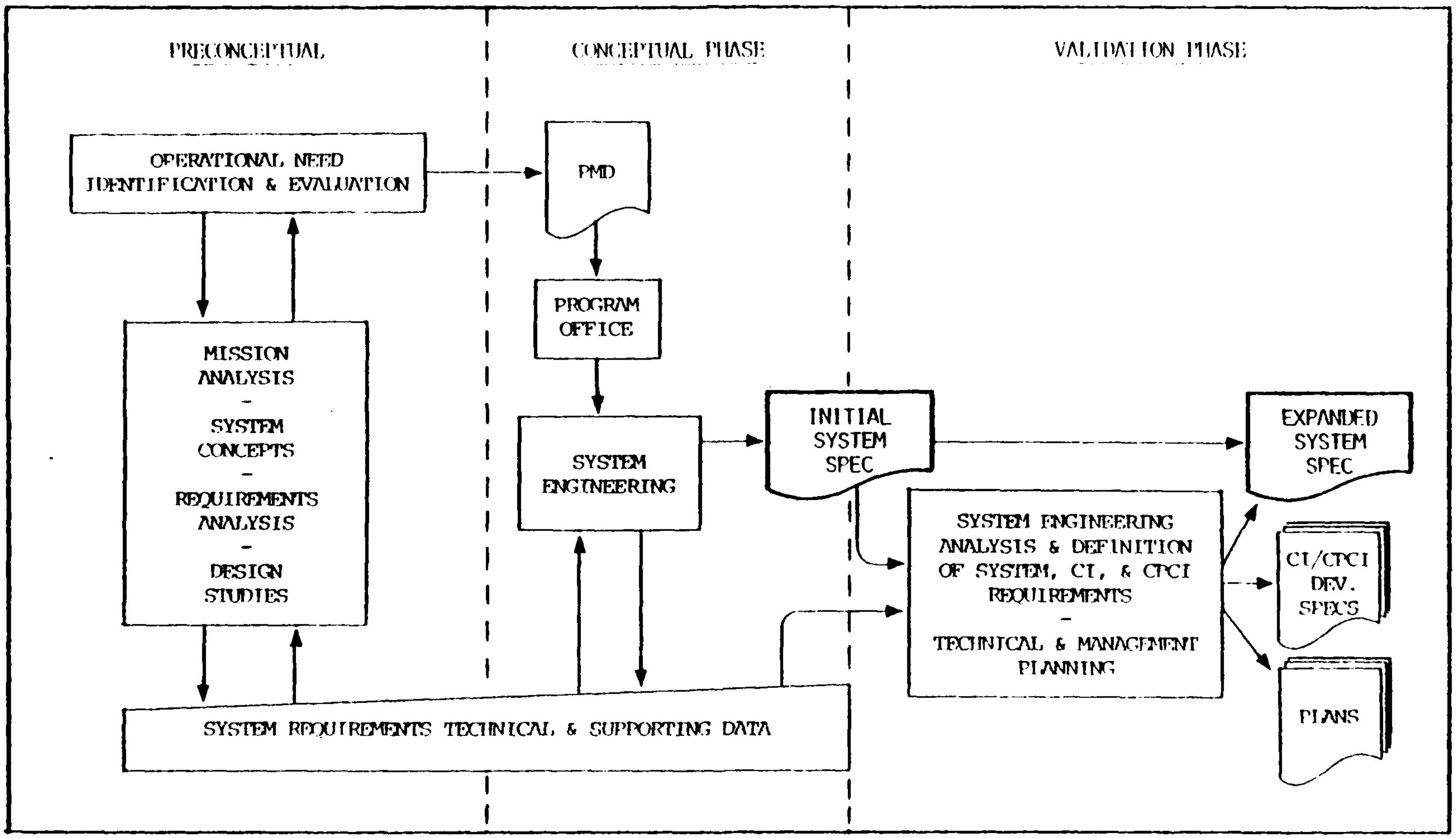

Figure 2-1. Phasing of System Specification Development.

specification should exclude performance and/or design requirements that depend on questionable technology, either hardware or software.

d. A validation phase has not often been conducted for electronic systems, possibly because the basic hardware is not typically subject to risks that can be effectively reduced through such activities as hardware proofing and prototype demonstration. However, the typical problems that do occur indicate that *a validation phase should normally be mandatory*, for the primary objectives of (1) accomplishing sound management planning and (2) completing the definitions of requirements for the system and its configuration items at levels that are adequate for undertaking the system full-scale development.

Later subsections of this section are organized to correspond individually with the three periods of time indicated above in Figure 2-1. The period labeled "Preconceptual" in the diagram represents the period of program initiation, for which requirements governing formal documents to be prepared by the commands and processed through Headquarters U.S. Air Force (HQ USAF) are prescribed in AFR 57-1 (12 June 1979). Significant aspects of those formal requirements to be considered in relation to the technical program are summarized briefly as follows:

The potential beginning of a system acquisition occurs when an operational command identifies a need for improved capabilities to perform its operational mission, in the course of on-going analyses of its ability to achieve assigned mission objectives. Through joint analysis and coordination with other commands, including AFSC, the need is documented in the form of a Statement of Operational Need (SON) and submitted to HQ USAF for evaluation.

The SON evaluation stage may include the preparation of a Mission Element Need Statement (MENS) by HQ USAF for submittal to the Secretary of the Air Force if indicated by size, scope, or other criteria which would indicate a major defense system or Air Force Designated Acquisition Program (AFDAP). Validation of the SON or approval of the MENS constitutes the milestone zero decision, authorizing commitment of resources. These actions are documented in the Program Management Directive (PMD) issued by HQ USAF to authorize formal initiation of the conceptual phase.

When the SON has minor impact or involves minor risk, milestone decision authority may be delegated to the implementing command, through issuance of a PMD in which HQ USAF specifies limiting thresholds, constraints, and objectives for the program.

As submitted by the operational command, the SON itself must be confined to documenting the need or deficiency in functional terms, without specifying or recommending a specific solution. However: (a) it may include an attachment which identifies alternative candidate solutions; and (b) further studies by other commands (notably, AFSC) are to be accomplished and reported during the period of SON evaluation.

2.2 The System Engineering Process

Considered very generally, system engineering is the multi-disciplinary activity which begins with functional analysis and arrives at a total system design, through a process which considers and evaluates a spectrum of military, economic, and technical variables that are relevant to candidate approaches. The process has been described more specifically as consisting of the following principal steps:

a. The first step is to identify the mission element need to be met by the system, e.g., as stated in the SON, and translate that need and its subelements into major functions of a projected system. For example, if the need relates to continental defense against a cruise missile threat, the analysis might result in identifying such major functions as air surveillance, target identification, weapons control, and battle assessment. Insofar as possible, emphasis is maintained purely on functions without regard to whether they will be performed by people, hardware, or software.

b. Each function is analyzed in relation to the projected military environment to identify subfunctions and associated performance requirements. Performance requirements are matters of speeds, capacities, accuracies, and similar criteria which bear on the manner in which each function must be accomplished. This step may involve analysis and evaluation of alternative solutions, at the functional level. It also includes the identification of functional interactions (interfaces) with other, existing systems.

c. Alternative approaches to design of the system--i.e., in terms of its physical configuration--are identified, initially in terms of major subsystems or system segments*, and trade studies are performed as needed to select a preferred design solution at that level.

Those steps are not intended to be performed discretely in the sequence outlined. Each step typically imposes needs to iterate earlier steps; and the design solution tends to result from a process of successive approximations. One inherent objective is to arrive at an end design which fully reflects and is traceable to the basic functional and performance requirements derived from identified needs of the military mission.

Figure 2-2 summarizes the basic process described above, and also suggests that elements of this general functional analysis/design approach continue to apply at each successively-lower level of design as it occurs during a system program. Although labeled as the "system" engineering process, it clearly shifts at later stages to the levels of engineering design for which responsibilities are assigned to technical specialists in the system hardware and software components.

The fact that the term "design" applies at many levels has significant

*For Air Force systems, this step must include the application of acquisition management as well as technical criteria. In this context, the terms "subsystem", "system segment", and "functional area" are generally equivalent, with the exception that instructions provided in Appendix III of MIL-STD-483 may apply in special cases.

BASIC SYSTEM ENGINEERING PROCESS - SYSTEM LEVEL:

- IDENTIFY SYSTEM FUNCTIONS

  ↓
- EXPAND SYSTEM FUNCTIONS & DEFINE PERF/DESIGN RQMTS.

  ↓
- PERFORM TRADE STUDIES & ALLOCATE FUNCTIONS TO SYSTEM SEGMENTS

LEVELS OF ANALYSIS & DESIGN:

---- SYSTEM

---- SEGMENT

---- CI/CPCI

---- COMPONENT

---- ...

Figure 2-2. Generalized Elements of the System Engineering Process.

management implications, as well as technical, throughout the course of a system acquisition. Generally, acquisition responsibilities are assigned to DoD components, commands, agencies, contractors, and their organizational units at identified levels of system or configuration item design. Management techniques are associated with organizational responsiblities at all levels, which depend upon the technical design solutions and at the same time impose constraints on the design process. Those tend to be most visible in the form of policies that each system segment and configuration item must be defined in such a way that responsibilities for its development can be assigned to a single contractor/agency, and of subsequent requirements to maintain traceable interrelations of technical products with such management instruments as statements of work, specification trees, organization charts, and work breakdown structures.

The relevant point for purposes of this discussion, however, is that the very first design decision which occurs to initiate that whole general pattern is the one which identifies the new system itself. While that decision is closely linked with the analysis of mission needs for which an operational command is primarily responsible, it is neither a direct result nor a direct purpose of the mission analysis as such. Rather, it should normally be a result of associated system engineering efforts, preferably carried out by activities which can provide continuity with later efforts by the implementing command to develop the system specification. The description of early activities provided in the following section is based on this general premise.

2.3 Generation of the System Concept

This description outlines the nature of preliminary technical tasks which should be accomplished prior to the beginning of formal specification preparation. The specific technical steps, and the total time span over which preliminary studies should occur, are subject to wide variations for different systems. Hence, emphasis in this description is placed on levels of design decisions and types of related technical information which should result from these early studies, rather than on a fixed flow of events.

For an electronic (information processing) system, the first and major objective of this period as a whole is to arrive at a firm definition of the system concept. Associated objectives are to acquire and document information pertaining to system requirements, design approaches, and constraints, initiating the essential base of background technical data which will be needed for continued use and expansion at later stages.

2.3.1 Initial System Concept

Not all SONs are subject to solution by new system developments. When they are, however, the initial concept for a new system is likely to be related to the mission analysis activities which led to identifying the operational need or deficiency. Such factors as obsolescent technology, opportunities to exploit new technology, and known changes in the threat environment have often pointed already to the general nature of a possible new system by the time they are reflected in statements of need for improved operational capabilities. A new or modified computer-based system is clearly suggested, for example, by the identified inability of a command to handle information processing and communications functions associated with a new surveillance technique, weapon, threat, or area of military operations.

While associated information about the system functions and probable design characteristics may be fairly extensive at the outset in some cases, the initial system concept is rarely adequate as a basis for starting the system program. However, the concept of a system, as such, is an indispensable starting point and guide for the further studies outlined below. In the course of further examination, the initial concept may be confirmed and refined, altered, or perhaps abandoned in favor of alternative solutions to the operational need.

2.3.2 Operational Requirements Analysis

Expressed in summary terms, purposes of operational requirements analysis are to identify elements and subelements of the operational command mission which the projected system is intended to support, translate those into system functions, and identify performance requirements associated with the functions. "Requirements" refers here to functional and performance characteristics of the projected system, as distinguished from "needs" which refer more directly to the command mission. Except for that difference in orientation, this first-level system analysis activity is necessarily carried out in close coordination with, and with continuing active participation by, the operational command.

Once designed, it may be assumed that the electronic system will consist of such elements as digital computing and communications equipment, computer programs, personnel, facilities, and possibly sensors or vehicles. In the operational analysis activity as such, however, the focus is on the scope and nature of mission elements, relevant factors of the operational environment, and derived requirements for data outputs, inputs, and processing. It is not normally practical to exclude design considerations altogether, particularly in view of the fact that this level of analysis must be iterated and refined at later stages of the system program. However, they should not be permitted to divert attention from the mainline purpose of identifying and defining functional requirements in the operational context, since those will become the working criteria against which design alternatives are selected and evaluated.

Methods and areas of emphasis for early stages of the analysis necessarily vary as a function of the nature and complexity of the mission elements involved, levels of information already acquired by the operational command organization, and similar factors affecting the degree to which an initial system concept is related to firmly prescribed mission tasks. Successive iterations in some aspects of the activities outlined below will be required as the program moves into later stages to arrive at the comprehensive definitions of operational requirements which will be needed before the system specification can eventually be completed.

a. The initial task is to translate mission elements into identified functions of the projected system. Generally, this translation consists of identifying operational processes necessary to accomplish the assigned military responsibilities and objectives; and it often involves significant attention to delineating the system mission scope, as well as its nature. In some cases, answers to questions in this area may be clearly indicated in the SON. In others, substantial effort may be needed to explore relations of the identified need or deficiency to a viable system concept. Occasionally, circumstances may point to the advisability of identifying a limited set of functions to be further defined for the given system program, reserving others for longer-range planning. However, to provide a sound basis for the system program at hand, an essential objective of this activity is to arrive at a definition of the system's major functions in terms of both their focus and clearly-delineated boundaries.

b. The functions of an electronic system are characteristically functions of data processing. Effectiveness of the system as a device to support a military mission will eventually be assessed in terms of its ability to provide data (or information) outputs which meet criteria in such areas as accuracy, timeliness, and sufficiency. Thus, the technical content of the analysis should consist in large part of identifying the required data outputs, then tracing the manner in which those outputs can be generated through processing operations performed on available system inputs. For early purposes--i.e., of defining the system concept at levels adequate for initiating a scheduled acquisition program--information about types of inputs, processing operations, outputs, and associated performance requirements should be acquired and documented at the relatively gross level of major system functions. These major functions are often identified to correspond with areas of the assigned military mission (e.g., Operational Planning, Weapons Control, Strike Effect Evaluation). To support continuation of the system program, however, this effort must also include the systematic collection and documentation of information in the related areas outlined below.

c. The documentation of detailed operational requirements at lower levels should be initiated as early as possible, and expanded as rapidly as events and available manpower will permit. Eventually--preferably before the end of the validation phase--precise and detailed definitions will be needed for every single type of data input, processing operation, and data output. Inadequacies in this area are a chronic problem, due to the typically massive quantities of that information. While there are automated techniques that can assist in some of its aspects, the basic task of identifying and verifying user requirements associated with each and every data item is inescapably manual. As a rule, the collection of properly-documented data item requirements for a large fixed data base, and for external message interfaces with other existing systems, should be well under way by the time the SON is validated.

d. As indicated above, the operational requirements analysis is primarily concerned with functions and performance. However, design considerations cannot be excluded altogether, since they inevitably influence the nature and form of major functions chosen for analysis, even at the system level. Major design constraints are often imposed explicitly by policy, or implicitly by obvious considerations of technology or expense; functions as such will be defined and carefully analyzed only when there are reasonable grounds to believe they can be implemented. Hence, a base of design documentation should be initiated at the outset which can be progressively expanded and refined during the course of later activities. At each stage, it should identify known design constraints, design alternatives, and identified questions of feasibility deserving further study. At early stages, particular attention is needed to identifying (1) design assumptions, where they may affect the functional analysis, and (2) needs for special research or feasibility studies which require long lead times to yield usable results.

2.5.3 Design Studies

Current policies for major defense system acquisition recognize the need for design studies during the preconceptual period for purposes of identifying and assessing alternative solutions to design of the system as a whole. AFR 57-1 assigns responsibilities, jointly to AFSC, AFLC, AFCC, and ATC, to identify constraints that limit alternative solutions and compare candidate alternatives with respect to technical and other factors of feasibility. In conjunction with these activities, AFSC must also prepare a program management plan for the succeeding phases.

Major alternatives for electronic systems tend to be matters of design in such areas as command organizational structure, geography or deployment, communications, and data processing technologies. Where significant questions exist, special studies may be indicated to assess alternatives with respect to relative effectiveness, technical feasibility, costs, development times, and support factors. The particular nature and emphasis of these studies should generally be dictated by design requirements derived from the preceding analysis of functions for the given system. Just how far the system design should have progressed by the end of this period is a question to be resolved in the light of such considerations as the following:

a. The system configuration--and each realistic alternative, if any exist--must be determined at a level which is adequate for program management planning purposes. Estimates of feasibility, costs, procurement approach, and schedules should be based on projected system support, including training and training equipment, as well as system operational functions.

b. In accordance with general Air Force policy, unnecessary limitations to subsequent design solutions by competing sources must be avoided. This policy is most clearly pertinent to design in the areas of system hardware and software components.

However, questions of system configuration which require long lead-times for their solution, or which must be resolved primarily through inter-command efforts and decisions, should be firmly resolved before the next phase begins. Such questions tend to be characteristic of electronic systems. As one example, extensive studies and coordination were needed over a lengthy period to arrive at a viable gross configuration for an air defense system in terms of numbers and locations of direction centers, taking into account interactive relationships with surveillance radar locations, command centers, air bases, communications, and command organizational units. Decisions at that level, which establish a known framework of major parameters and boundaries for the system, are generally essential as a basis for delimiting the potential scope and emphasis of system engineering/information processing analyses at later stages.

2.4 The Initial System Specification

The Program Management Directive (PMD) issued by HQ USAF to initiate the conceptual phase includes directions for funding, schedules, approval actions, and program management objectives which are tailored to each program. The description provided in this section assumes that the recognized primary technical objective of this phase, for a major electronic system, is to develop an adequate initial system specification.

The system program is managed during this phase by the Program Office (PO) established by AFSC in response to the PMD. The PO is the designated central office having Air Force responsibility for planning and management of the program as a whole, including contracting, logistic support, program control, and related support management areas as well as engineering. Participation by other commands and Government agencies is provided through representation in the PO organization. The actual conduct of continued studies in the technical (engineering) area is carried out with additional support by personnel of AFSC laboratories, a Federal Contract Research Center, or system engineering contractors.

2.4.1 System Engineering Analysis

Major types of activity involved in the process of developing information to be provided in (or with) the system specification are outlined in Figure 2-5. Although the activities are highly interactive, as the figure suggests, the effort as a whole should be planned and structured to emphasize the immediate goal of yielding information in the many categories, and at the levels, which the initial system specification requires. Once the conceptual phase formally begins, the end products of these efforts must generally be accomplished on a time schedule which is relatively short and fixed, as compared with the precedir period. However, demands to maintain flexibility are inherent in the system engineering process. To the degree feasible, efforts should be planned and managed to provide for repetitions, expansion, or redirection as indicated by actual progress and results.

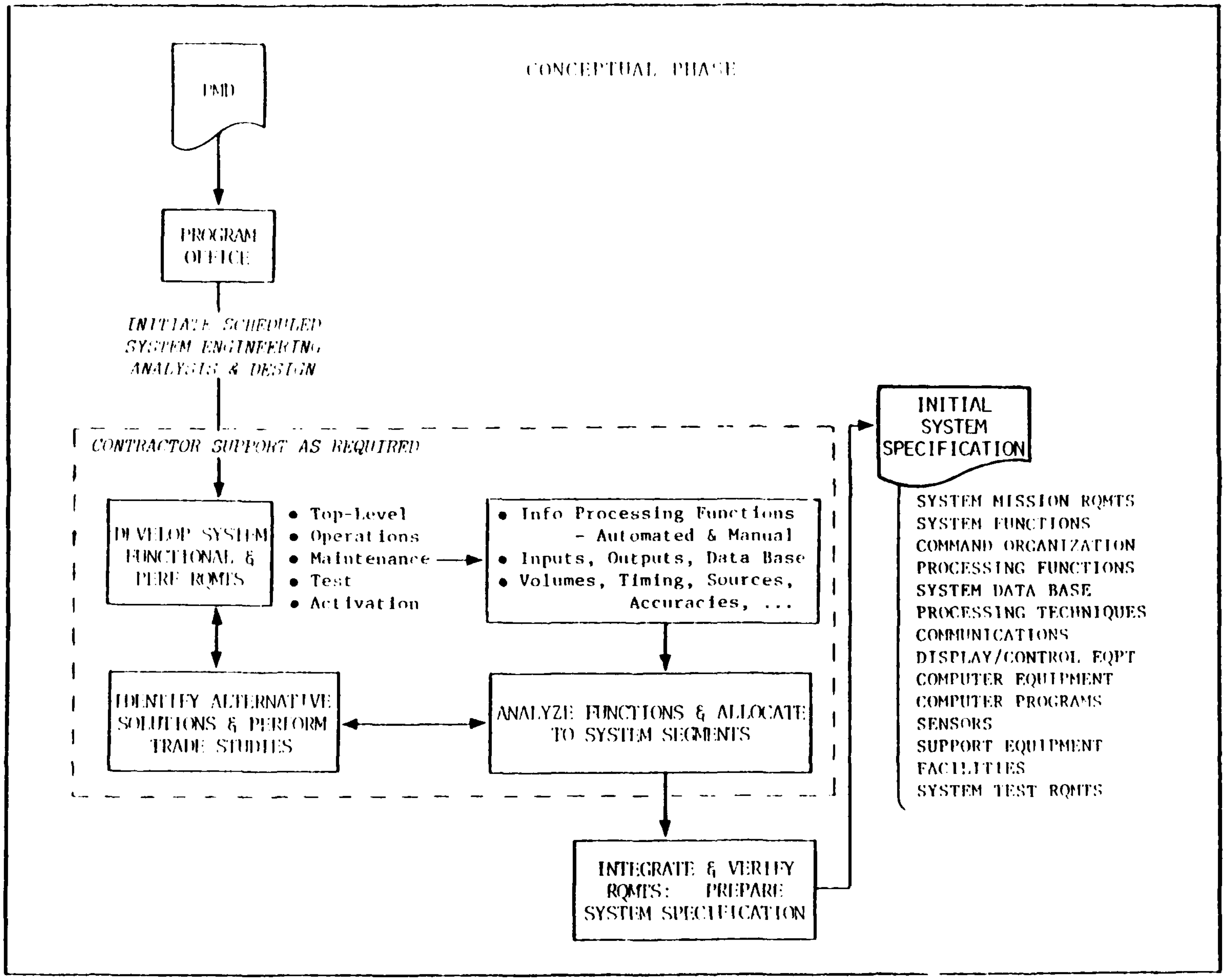

Figure 2-3. Overview of Conceptual Phase Analysis.

Figure 2-4 identifies a sequence of major tasks and logical steps involved in the process represented in the preceding figure. Narratives below are keyed to block numbers shown for the steps. On the whole, this description is limited to a summary of the "mainline" process; the full scope of activities in a given actual case is clearly much more complex.

TASK 1 - FUNCTIONAL ANALYSIS

The objective of this task is to collect, organize, and analyze information about system operational functions which will provide (a) direct inputs to system definition and performance characteristics portions of the system specification and (b) the functional requirements basis for further study of support functions and requirements/constraints for system design.

Block 1.1 Collect and Organize Technical Data. An essential early step is to establish a data bank of existing information about the system. This activity should begin by compiling, reviewing, and assessing the source documentation resulting from the preconceptual period studies. Centralized files should be organized to provide for continuing access and expansions as the analysis proceeds.

Block 1.2 Develop Functional Flow Diagrams. This activity is based on operational requirements and gross system design decisions resulting from earlier studies; it includes additional studies to expand that information as necessary to ensure its completeness and accuracy with respect to military objectives, constraints, and the operational environment. The activity consists of developing functional flows and systematically documenting those in forms suitable for use in subsequent steps of the analysis.* Initially, system requirements are translated into one top-level diagram which identifies the gross mission operations together with test, production, deployment, and support functions.

*While functional flow diagram formats are optional, clear and consistent rules for a selected approach should be established at the outset of each project. For purposes of this description, they are assumed to be developed in accordance with rules and widely-established uses of the diagrams as outlined in DI-S-3604.

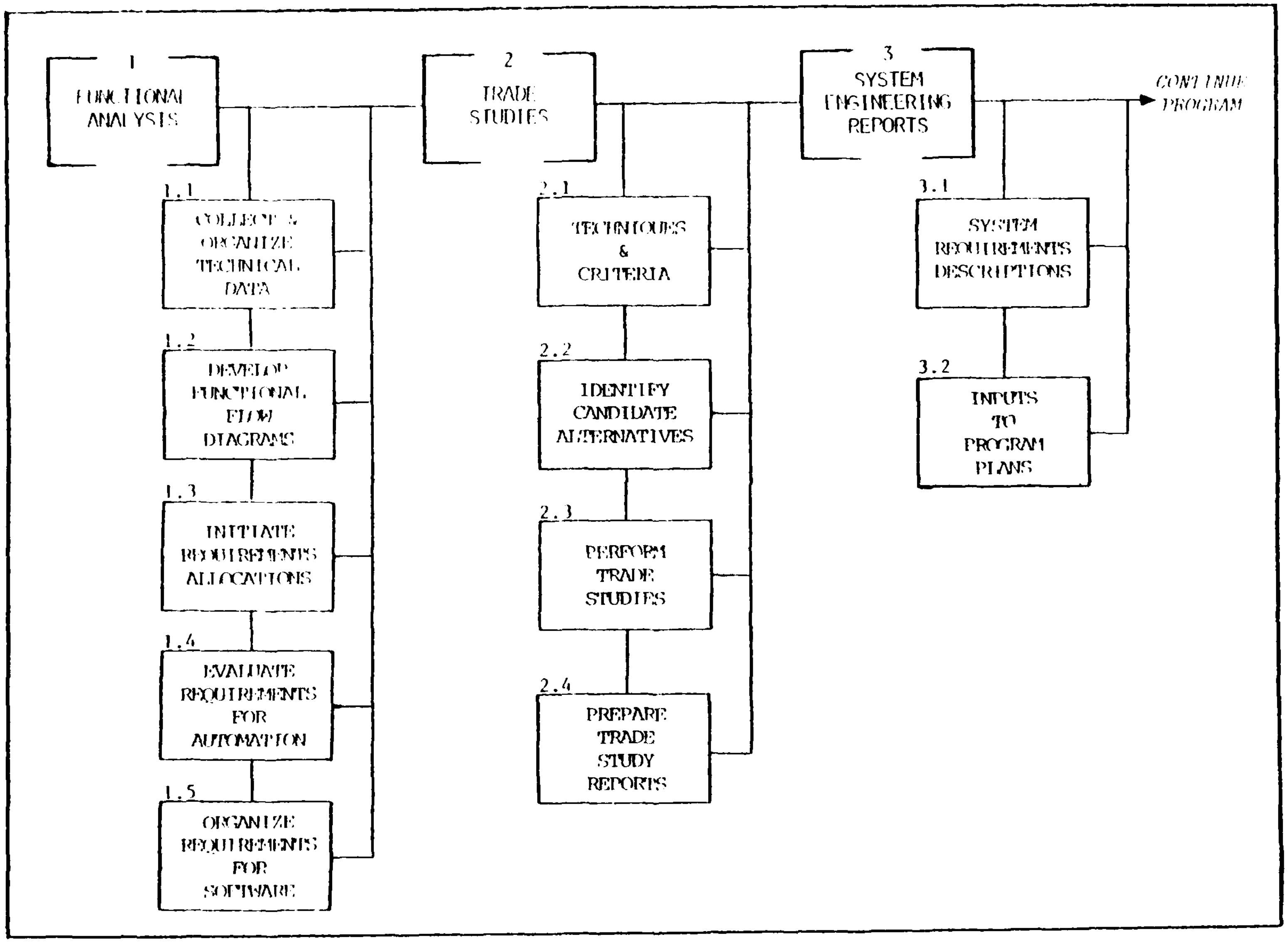

Figure 2-4. Flow of Major Technical Tasks Conceptual Phase.

At this stage, flows should be further developed for the mission (operational) functions at the first and second levels, at a minimum, and at lower levels for selected subfunctions as needed.

Block 1.3 Initiate Requirements Allocations. The systematic allocation of requirements to system segments is initiated at this stage to provide a basis for subsequent studies of design alternatives at lower levels. System segments (subsystems, or functional areas) are likely to have been identified in a preliminary way at earlier points in time; but their verification and precise delineation is a progressive process which will not be fully completed until the end of the validation phase.

This step should include reviewing and assessing one or more proposed breakdowns of the system into segments for soundness in the light of available criteria. Each segment is a major part of the system which (a) is characterized as a technically-consistent grouping of system elements designed to perform assigned portions of the system functions, and (b) represents an area of developmental responsibility which must be assigned to a single contractor or Government agency.* This allocation activity itself serves to verify or alter the preliminary identification of system segments, in that a sound breakout should permit all requirements to be precisely allocated without creating complex interfaces among the segments.

The allocation process begins with system functions identified in the preceding step. It consists of assigning the functions, subfunctions, and performance requirements to the segments in such a way as to identify technical design criteria which will apply to specifying combinations of equipment, personnel, and facilities needed to perform each function. Systematic documentation is a fundamental necessity, due to the sheer volumes of information involved as the process continues during this and subsequent tasks. Types of system engineering documents which should be generated by this activity--and controlled during later expansions--are exemplified by the Requirements Allocations Sheets and Schematic Block Diagrams described in DI-S-3605 and -3607.

*This is not to say that each segment must be assigned to a separate contractor/agency. All requirements may be assigned to a single contractor; however, the breakout still serves significant purposes of management visibility and control for both the Air Force and prime contractor.

Block 1.4 Evaluate Requirements for Automation. This activity consists of analyzing performance/design requirements and constraints associated with system information processing functions for man/machine allocations. System inputs and outputs are examined with respect to such characteristics as sources, frequencies, volumes, formats, contents, security, timing, accuracy, and associated implications for the involvement of system personnel in their generation or processing. Decisions are based on evaluating functions and requirements in the light of such factors as technical feasibility, costs, timing, and inherent needs for on-the-spot judgment or intervention. This analysis should proceed to the point of allocating functions among the following three categories:

a. Manual - essential decision-making, coordination, analysis, or control functions to be performed by command or staff personnel which do not imply direct interaction with system input or display equipment.

b. Automated - functions performed by equipment without manual intervention.

c. Man-Machine - functions performed primarily by personnel, but involving direct interaction with automated system functions/subfunctions through manual input and display devices.

This step as a whole should be accomplished comprehensively for the system operational (mission) functions and for major support functions derived from the known operational requirements--for example, functions of simulation, data recording, and data reduction involved in system test and evaluation or training. Although information about support functions is likely to be variable, particular effort should be taken to ensure that general requirements are identified that will affect the scope of needs for system personnel, hardware, and software.

The significant initial result of this activity is to arrive at a first-level separation of system functions assigned to the two major classes of elements which perform data processing operations in an electronic system--namely, personnel, on the one hand, and a set of automatic data processing (hardware/software) elements on the other. In the case of personnel, this and later steps are directed towards (a) identifying the types, levels, and general characteristics of command and staff positions required to perform the identified manual and man-machine tasks, including impact on training needs and the operational command organization, and (b) formulating human factors engineering requirements to be imposed on the system data processing hardware, software, communications, and facilities.

As regards automated elements, the emphasis at this stage is on collecting and detailing requirements for information processing functions which will be further allocated eventually as between digital computing/communications hardware and computer programs. Immediate objectives are to identify and catalog those automated functions and derived performance requirements, encompassing both the purely automated functions and those associated with manual inputs and displays.

Block 1.5 Organize Requirements for Software. A final step in this task is to integrate and organize data resulting from the preceding steps, and to translate the aggregation of those requirements into criteria for system computer programs. The process of integrating operational and support requirements must include their evaluation with respect to such characteristics as: adequacy in meeting mission needs of the operational command; environmental and organizational contingencies; functional interfaces with external systems/organizations; generation, content, and uses of fixed data bases; and major factors of loads, volumes of data, response times, growth potential, and security.

The integrated requirements for automated functions are analyzed initially to arrive at an overall assessment of the system software characteristics. During later steps, hardware and software trade-offs will be examined; and still later (during the validation phase), firmly-identified characteristics of the computer hardware will become a prerequisite to the identification of computer program configuration items (CPCIs) and the initiation of their development specifications. At earlier phases of an electronic system program, however, software is the "lead item" upon whose characteristics the determination of requirements for the system data processing hardware must be based.

In the system specification, software requirements will continue to be expressed predominantly in terms of functions and performance--and, in terms of functions and performance that will continue to be shared with computer hardware. The specification of software "design", as such, at the system specification level is limited to (a) general design requirements/constraints (e.g., design standards cited in paragraph 3.3.8) and (b) the structuring of software elements into CPCIs (to be accomplished during the validation phase).

However, further examination of software design approaches should be included as an important part of subsequent steps at this stage, in order to: verify feasibility and completeness of the requirements; identify and assess state-of-the-art techniques as they apply to relevant functions--e.g., data base management, time-sharing, parallel processing, communications, data access control; and furnish essential criteria to assist in determining requirements for the design of data processing hardware.

TASK 2 - DESIGN TRADE STUDIES

This task consists of a series of systematic analyses to assess the advantages and disadvantages (trade-offs) of system data processing design alternatives with respect to both hardware and software. The purpose is to construct a rational set of design concepts--i.e., a feasible system configuration--as a working basis for subsequent integration of system requirements information during the conduct of Task 3. By this stage, it is assumed that major parameters of the system configuration have been established through prior decisions, permitting these studies to focus on a relatively finite range of design alternatives. In each case, the identification of significant alternatives to examine is a matter of technical judgment based on knowledge of the given system requirements and constraints. Even with those limitations, it is not normally necessary or practical to analyze all possible alternatives exhaustively. The objective is to interrelate a set of realistic design solutions with system requirements in sufficient depth to assure that the requirements will remain valid during the course of later design trade studies at lower levels.

Block 2.1 Techniques and Criteria. A first step in this task is to provide working tools for the analysis activities. Techniques and criteria to be employed in conducting the analyses should be established at the outset in such areas as the following:

a. Analysis techniques for assessing design alternatives, including format and content of trade study summaries.

b. Functional and design requirements for specific trade studies.

c. Established constraints--e.g., with respect to facilities, power, environment, communications, manpower.

d. Evaluation criteria with respect to critical design objectives (loads, timing), secondary characteristics of equipment (the "-ilities"), and computer programming feasibility factors.

Block 2.2 Identify Candidate Alternatives. This activity involves the exercise of engineering/data processing judgment based on knowledge of hardware and software design approaches that are pertinent to the system. It is important that analysts be aware of the range of applicable technology during the time frame of the system program, able to identify the areas in which significant questions exist, and prepared to assess candidate solutions objectively. The activity consists of constructing an approach to the "system architecture" and, at this step, identifying alternatives--involving computer hardware, consoles/terminals, communications, and/or software--which merit further systematic comparison with respect to performance and factors of feasibility. As the task progresses, additional or related alternatives may be identified. However, the analysis as a whole will tend to be fruitful to the degree that the "right questions" are formulated at the outset.

Block 2.3 Perform Trade Studies. A trade study consists of comparing two or more candidate designs with respect to all of the characteristics which are important to the intended application. Characteristics to be considered include not only the identified performance requirements but also factors of cost, availability and/or development times, operability, maintainability, growth potential, safety, impact on interfacing or support elements of the system, and flexibility with respect to lower-level design solutions. Occasionally, certain performance aspects may be subject to analysis through simulations or mathematical modeling. Generally, however, the analysis consists basically of examining the advantages and disadvantages of each candidate, rating the candidates with respect to each relevant characteristic (including experience), and arriving at an overall assessment based on the complete set of comparisons.

Block 2.4 Prepare Trade Study Reports. Each study performed in the preceding step should be documented, preferably in a summary form similar to the Design Trade Study Report described in DI-S-3606. Backup data should be included where indicated to clarify the selection of alternatives, evaluation criteria, and identified questions or points of importance to be further investigated and reported by competing contractors during the validation phase.

TASK 3 - INTEGRATE AND DOCUMENT SYSTEM REQUIREMENTS

The function of this task is to analyze information available from preceding studies and document system requirements in forms which will be directly useful in preparing the system specification and associated program plans. Products should consist of (a) an organized collection of system technical data and (b) a report or series of reports containing summaries of the studies accomplished, inputs to program planning documents, and comprehensive recommendations for content of the initial system specification.

Block 3.1 System Requirements Descriptions. This step consists of compiling organized descriptions of information and requirements to be covered in Section 3 of the system specification. It involves reviewing information derived from preceding tasks, assessing it for completeness, and augmenting it by further analysis as necessary to provide recommendations covering (a) functional, performance, interface, and design requirements for the system as a whole and (b) allocations of the requirements to firmly-identified system segments. Descriptions in the significant areas listed below should be supported by functional flows, schematic block diagrams, and other system engineering documentation relevant to each area:

a. System definition. Descriptive material defining the system as a whole should be provided, covering mission objectives and constraints, integration with other systems/capabilities, operational and maintenance concepts, characteristics of the threat, and other aspects of the mission affecting design requirements for the system.

b. Interfaces with other systems. For an electronic system, inter-system interfaces are matters of communications, relating to both (1) characteristics of automatic data and/or voice communications media (hardware/software) and (2) messages, to be output and received by the given system. All of those must be identified at this stage and also defined, at least in functional terms, at levels sufficient to delimit their scope and nature. However, a considerable portion of this effort is likely to be spent in searching, compiling, and organizing data (or references to available sources) in the form of detailed definitions which already exist for interfaces with external systems and organizations--often at the level of message types, formats/contents, frequencies, and volumes, together with known characteristics of the communications links. Those constitute predetermined constraints for the new or modified system which should be identified comprehensively in advance and made visible in the initial system specification.

c. Command organization. The command organization should be described in terms of levels of command, mission responsibilities of identified organizational elements, and functions to be performed by those elements at specified operating locations. It should include a preliminary estimate of types and numbers of personnel required for system operation and support, taking into account the projected locations, normal and emergency operating modes, and planned duty cycles.

d. System performance. This description should include coverage of: identified modes and phases of system operation; performance requirements for the system as a whole; and performance requirements for identified system functions and subfunctions. Performance requirements for the system as a whole normally relate to total system capacities and/or response times--e.g., total capacity for handling target tracks or simultaneous intercepts; minimum times to accomplish threat identification and warning or other action. Descriptions of information processing functions should emphasize coverage of operational and support functions at the higher levels--i.e., those identified in first- and second-level functional flow diagrams--but should also extend to lower levels to the degree indicated in each area by verified operational needs or design constraints. Each function/subfunction is described in terms of identified function inputs, outputs, and processing operations, together with associated performance requirements. At this stage, a large body of detailed data should exist pertaining to the inputs and outputs, in particular, organized in a form that can be referenced here and made available for later uses. If the system involves a large data base, the description should include identification of the data categories and types, estimated sizes of files, references to existing data definitions, and requirements/responsibilities for data collection and maintenance.

e. Allocations to system segments. A significant part of the final report should be devoted to the grouping of performance, design, and interface requirements into system segments. The segments are identified by titles and defined, basically, by their allocated functions and requirements. All functions and performance requirements (see d above) should be accounted for, including total system requirements which are apportioned between two or more segments. At the performance level, allocations should be supported by schematic block diagrams (first-level) in which functions assigned to the segments are traceable to the system functional flows and the nature of functional interfaces is clearly identified. Interface requirements imposed on each segment include both functional interfaces that are identified and defined with other segments and external system interfaces, as allocated.

The primary functions being allocated are ones which will be performed through the combined operation of command personnel and computer programs, operating in the context of general-purpose digital computing equipment, display/manual input devices, and communications links. Analyses performed during preceding tasks will have extended the system segment allocations to the point of identifying further requirements and constraints for segment design with respect to those elements. The description provided here should include a full account of those extended results, together with recommendations for the levels of design requirements to be imposed on each segment. Recommended and limiting characteristics should be identified in such areas as the following:

--General logical and physical equipment configuration and geographic locations.

--Estimated numbers and processing characteristics of computers--speeds, capacities, word structure, or other design constraints.

--Estimated numbers, types, and capacities of peripheral devices and requirements for special synthetic signal/message generating or interface equipment.

--Numbers, capacities, and types of operator consoles, terminals, or special simulation consoles, together with input/control and display requirements; requirements for special displays (e.g., large wall) or hardcopy printers.

--Recommended structure and characteristics of mission/operational and support computer programs--e.g., language forms, data base management, operating system, simulation/data reduction, maintenance/diagnostics.

Block 3.2 Inputs to Program Plans. During the course of the three system engineering tasks outlined above, the Program Office has also been responsible for preparing, coordinating, and integrating appropriate planning documents to support the milestone I decision. The Program Management Plan (PMP) includes a prominent section (Section 4, System Engineering and Configuration Management) which should be based on information derived primarily from the technical effort. Other sections of the PMP and other plans are the primary responsibility of participating commands and such other elements of the PO as procurement, program control, and logistic support. However, most of those other plans depend heavily on inputs from the technical program to be accurate and adequate. Hence, in parallel and integrated with the conceptual phase system engineering analysis, significant engineering management efforts should have been accomplished to support the development of planning information in such areas as:

--Program Costs
--Master Program Schedule
--Statement of Work
--Preliminary Work Breakdown Structure
--Determination and Findings (D&F)
--Advanced Procurement Plan
--Source Selection Plan
--Real Property Facilities Plan
--Test and Evaluation Master Plan (TEMP)
--Integrated Logistics Support Plan
--Computer Resources Integrated Support Plan (CRISP)
--System Operational Concept

2.4.2 Preparation of the Specification

The system specification should be prepared before the end of the conceptual phase, initially in draft form for review and coordination by participating commands. Following coordination, it is submitted to higher headquarters as a part of the documentation package required for evaluations leading to the milestone I decision.

The preparation process involves translating the technical information described above into carefully-formulated statements of system requirements which comply with format/content instructions of MIL-STD-490, Appendix I, observing supplementary instructions provided in Appendix III of MIL-STD-483 (USAF) to the degree that those apply to the given program at this stage:

a. The decision may be made to write the specification in the form of one general volume and a separate volume for each system segment. In this case, the format should follow instructions in paragraph 30.6 of MIL-STD-483.

b. Content instructions provided in MIL-STDs 490 and 483 (para. 30.3) are for the fully-completed specification. At this stage, significant decisions to be made relate to the appropriate degrees of incompleteness at which requirements *should* be specified in certain areas. In general, complete and definitive requirements should be specified in most areas which pertain to system definition, design standards, and other characteristics of the system as a whole (i.e., covered in paragraphs 3.1 through 3.6 of the specification). However, requirements in paragraph 3.7 (Functional Area Characteristics) and 3.1.4 (System Diagrams), in particular, must be carefully formulated to (1) include all performance/interface requirements and design constraints which have been firmly established and verified at this time, but (2) permit maximum latitude for further analysis and hardware/software design solutions by competing sources during the validation phase.

2.5 Completing the System Specification - Validation Phase

Major goals of the validation phase are to expand and refine the system specification, establish firm performance specifications for configuration items which meet system requirements, and promote the accomplishment of comprehensive contractor planning for system development which is realistically consistent with reduced program risks.*

The technical studies of principal interest to the process of expanding and completing the system specification during a validation phase are those conducted by contractors. However, the responsible Program Office must plan and manage this phase as a whole to encompass a total of three successive time periods:

← VALIDATION PHASE →		
PLANNING	**IMPLEMENTATION**	**EVALUATION**
• Update Program Plans	• Perform Analysis/Design Studies	• Evaluate Contractor Products
• Prepare & Issue RFP	• Expand System Specification	• Update System Specification
• Select Sources	• Prepare Item Performance Specs	• Update Program Plans
• Award Contracts	• Prepare Plans & Schedules	• Prepare for Milestone II

a. Planning is accomplished during an initial period following the milestone I decision. Significant effort is required to prepare program planning documents, issue the Request for Proposal (RFP) package, select sources, and award contracts.

b. Implementation is accomplished by the selected contractor(s).

c. Evaluation consists of assessing the results of contractor efforts, updating and expanding program plans, and preparing documentation required for the milestone II decision.

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*Amplified discussions of major and subsidiary objectives for the validation phase are provided in AFSCP 800-3 (Chapter 5) and AFSCP 800-6 (Chapter 6). See also 3.3 herein for a further discussion of risks encountered in electronic system programs.

2.5.1 Planning and Preparation

During this first period, the initial system specification prepared during the conceptual phase is reviewed and revised as necessary to reflect additional information or changes resulting from the milestone I evaluations and decisions. The system specification will begin during the next period to perform its significant role as the primary document governing technical objectives for the system program. After being established at this time by the PO's configuration control board (CCB) as the functional baseline, no further changes may occur except through formal processing and approval of engineering change proposals (ECPs). Expansions to be provided later by the validation phase contractors are included among "changes" which require that formal processing. However, effort should be made at this time to minimize the likelihood that those will need to include changes to the basic requirements; it is to be hoped that they can be limited to expansions involving further definition of system design with respect to hardware/software configurations within the system segments.

Evaluation of the system specification for adequacy should be supported actively by the operational command, as well as by such other available expertise that can be brought to bear by the Program Office, prior to issuing the validation phase RFP. Expressed simply, the important judgment to be reached is whether the projected system, if further defined and built to meet the requirements exactly as stated, will indeed meet needs of the operational mission. That judgment is necessarily an estimate; and it happens to be one which has proved, over the history of system programs, to be subject to a systematic bias: *Further work as the program moves downstream inevitably results in a better understanding of technical, cost, and time implications of the requirements as originally stated, and in discoveries of new requirements not previously identified--always, resulting in expansion.* That phenomenon has long been the chronic and major cause of cost/schedule overruns and program failures. To expect that its effects can be eliminated completely is unrealistic. But it represents the principal, known source of risk in electronic system programs which a validation phase, if properly planned and managed, can reduce to an acceptable level.

Related preparations to be accomplished during this period include the following activities:

a. Updating, coordinating, and issuing the Program Management Plan (PMP).

b. Preparation and release of the RFP package to potential contractors.*

c. Contractor preparation of validation phase proposals.

d. Award of validation phase contracts, based on proposal evaluations and source selection procedures.

The system specification is included in the RFP as a part of the statement of work (SOW), together with requirements for its further analysis and expansion by the validation phase contractors. Generally, the candidate contractors will have invested efforts in studies of the program prior to receipt of the RFP; hence, since they must also perform further analyses during the process of preparing proposals, the successful candidates should have accrued a substantial knowledge of the program by the time the next period begins.

System engineering documentation incorporated as firm requirements in the initial system specification (para. 3.1.4) will normally consist only of selected portions of the documentation generated during earlier studies (see 2.4.2 above). However, the PO should prepare a list of documents which have a direct bearing on the system, including conceptual phase studies, and provide copies of the list with the RFP.

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*This description assumes, for simplicity, that the system is to be procured (later, during full-scale development) through a single prime contractor. However, it may be a viable option in some programs to use associate contractors for separate system segments. In that case, the system specification will have been prepared in the form of one general volume and separate volumes for the segments; and competition, during validation, would be by competing associates. Technical activities should be basically similar to the degree that each segment--consisting in itself of separate functional areas--merits a comparable approach to its analysis and design.

2.5.2 Implementation

Descriptions provided below of technical activities performed by contractors during this period follow the synoptic outline of events depicted in Figure 2-5. Activities shown in the figure are limited to those leading directly to major products mentioned earlier relating to the system specification, item specifications, and program plans. It is conceivable that reasons could exist to require a prototype (i.e., partial prototype) demonstration as a part of this phase. In that event, there would be additional activities which would interact with, but should not replace, these mainline activities.

This phase as a whole is described below as consisting of three successive stages: (a) a first stage devoted to meeting technical objectives reflected in requirements for the System Requirements Review (SRR); a second stage which terminates with successful completion of the System Design Review (SDR); and a final period during which contractors complete and submit all products for this phase required by their contracts.

2.5.2.1 System Definition

The contractor's efforts at this initial stage should be devoted to expanding the system engineering studies described above for the conceptual phase (2.4.1). The technical approaches should be basically similar; however, they are now guided by firm decisions reflected in the initial system specification, and by known requirements (stated in the SOW) for studies in specific areas indicated by results of the earlier work. Hence, while the contractor should study and understand the mission, functional, and performance analyses accomplished previously at the higher levels, he should not be required to iterate those. The major emphasis at this time should be placed on: (a) expanding the analysis of functions to lower levels; (b) determining design requirements for the system segments; (c) performing trade studies to evaluate both functional and design solutions; and (d) arriving at allocations of the requirements to identified hardware and software items within each system segment.

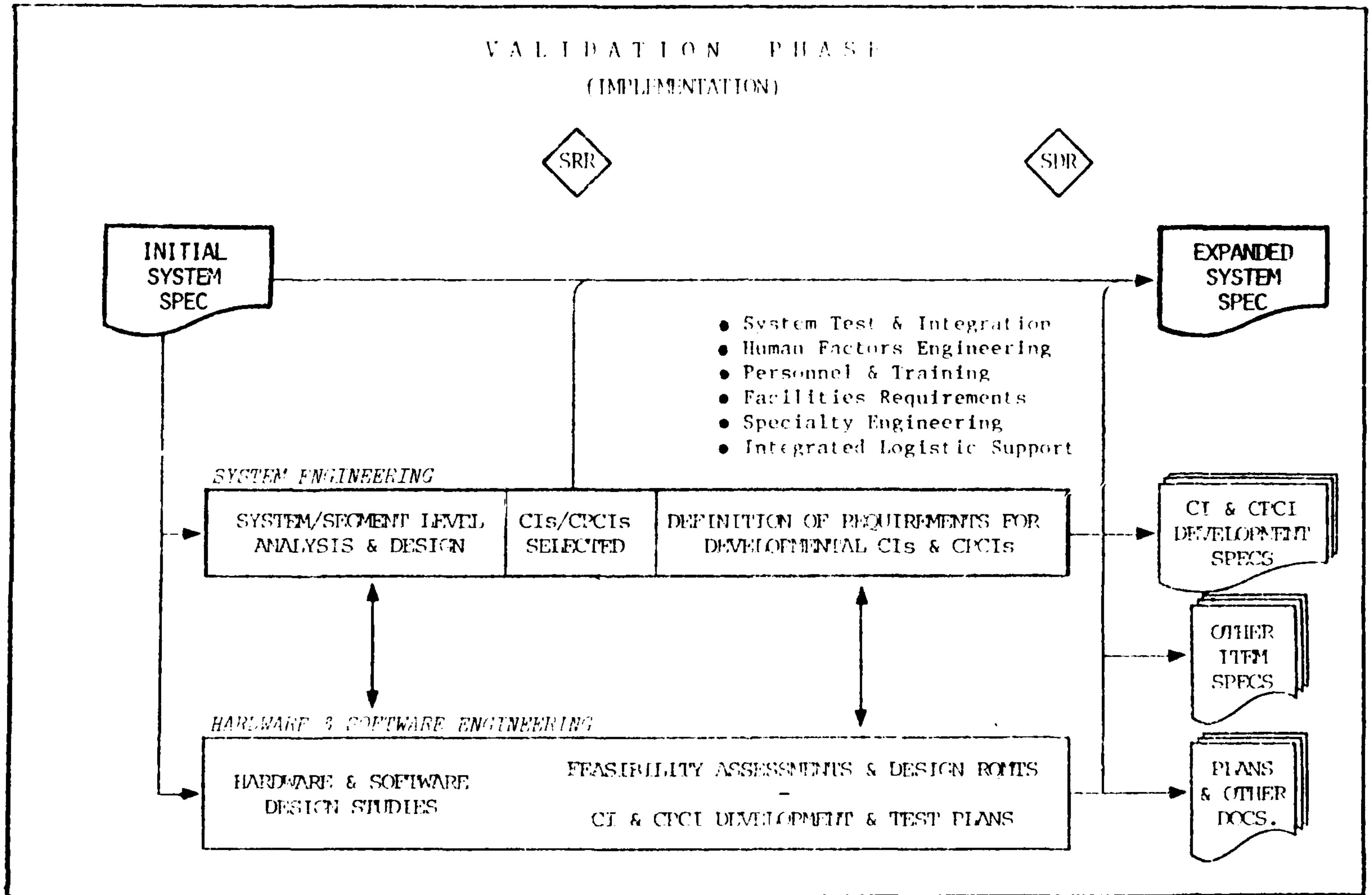

Figure 2-5. Outline of Validation Phase - Implementation Period.

The purpose of SRR is to review and evaluate the contractor's progress in accomplishing those tasks, as they contribute to specifying functional and physical characteristics of the system as a whole. As indicated in Figure 2-5, the last step mentioned is probably the most visible single indicator of whether the SRR objectives are being met.* The system specification will not be fully completed until all items can be identified (in paras. 3.1 and 3.1.4) by CI number or equivalent, approved nomenclature, and specification number. The total listing will identify all commercial and Government inventory as well as developmental items, and all items required for support as well as for operational functions of the system. Some of the minor items need not be precisely identified until later. However, the list should be complete at this point in the program with respect to all items upon which the ensuing validation phase activities are dependent. Those include both: (a) existing items (e.g., computers, consoles, and major items of support software) which affect the content of subsequent studies and planning, and (b) items of new development for which development specifications are to be prepared during the next stage.

Evaluation of the proposed hardware/software configuration for each segment should be based on consistency with documented design requirements derived from the functional allocation and trade studies, and on compliance with management criteria set forth in such sources as AFSCP 800-7 and MIL-STD-483. Those sources recognize that the item selection process is largely a matter of judgment, involving experience and awareness of the relevant technical and management considerations. However, the established criteria for the selection of "configuration items" tend to apply most directly to items of new development. Some special questions encountered in dealing with mixtures of commercial and developmental elements, which have been characteristic of electronic system programs in recent years, are discussed in the next section (see 3.2).

*Although referred to here as a single event, SRRs may be scheduled on successive calendar dates to correspond with expected progress (a) initially, in defining the system configuration for operational functions and (b) later, in defining derived requirements in such areas as logistic support, facilities, the specialty disciplines (reliability, maintainability, ...), engineering integration, and test planning.

2.5.2.2 Configuration Item Definition

The identification of items accomplished in the preceding stage represents the completion of design, as such, at the level to be specified in the system specification. Iterations, refinements, and some expansions of the system specification should continue to occur throughout the remainder of this phase. However, the principal focus of the system engineering effort as a whole shifts at this point to concern with requirements for the individual items. In general, major technical activities are now devoted to supplementing the system specification with item-level specifications and other documents which expand the definitions of requirements allocated among the identified system components--including personnel and facilities as well as hardware and software. The varied and interrelated activities which should be completed--or nearly completed--by the time of SDR include those summarized very briefly below:

a. Generation of the allocated baseline. The most prominent activity during this stage is concerned with developing or acquiring the complete set of item level specifications which will constitute the system allocated baseline when completed and approved. The allocated baseline encompasses the totality of system requirements allocated to items of hardware, software, and facilities. It is documented in the form of specifications which will be placed on contract during the next phase of the program to govern the development or other acquisition of those items. As identified in the system specification (i.e., in the specification tree, para. 3.1.4), those may include most or nearly all of the following types and forms:

   (1) Computer Program Development Specification (Type B5). By and large, most of the operational functions of an electronic system are allocated to computer programs. The process of generating a B5 specification involves further analysis of the allocated functions to much lower levels than they are specified in the system specification. In terms of total time, manpower, bulk of essential detail, and direct significance to the operational mission, this task should normally account for most of the system engineering effort expended during the validation phase as a whole.

(2) Hardware Development Specifications. Although electronic system programs do not typically include the development of major items of new aerospace equipment, there are normally some items to be newly developed (or undergo major modification, e.g., a console or communications element) which require the preparation of development specifications. Depending on the item complexity and other factors, the specifications prepared at this time will be Type B1 (Prime Item), B2 (Critical Item), or B3 (Non-Complex Item).

(3) Facility Specification (Type B4). The system specification identifies facilities with respect to intended use, general characteristics, and status--i.e., whether existing, to be modified, or to be newly constructed. The preparation of a Type B4 specification is initiated at this time for facilities requiring new construction or major modifications. Requirements are derived largely as a part of the on-going analyses of requirements for system equipment and personnel.

(4) Other Specifications. In terms of numbers alone, most of the specifications to be prepared or acquired at this time are likely to be for existing items of hardware and software. Depending on sources and other factors, these will include: Type C4, for items already in Government inventory; specifications to commercial practice (MIL-S-83490 Form 2 or Form 3); or product function specifications, Type C1a or C2a. Although classed as "product specifications", these should generally be approved and controlled as part of the allocated baseline for the reason that they constitute the only requirements documentation to govern the acquisition of the items during full-scale development.

b. Personnel and training requirements. This activity consists of developing information relating to numbers and types of personnel needed for field and organizational operations and maintenance, and to projected needs for individual and team training. Earlier estimates of personnel requirements are refined during this period largely on the basis of data derived from the on-going analyses of requirements for equipment and computer program CIs, supplemented by additional analysis normally required to develop the standard qualitative and quantitative personnel requirements information (QQPRI) report. Depending on the system, significant additional efforts may be involved in developing requirements for capabilities that can be used by the operational command to perform simulated exercises for purposes of system training and evaluation.

c. Item-level development and test plans. Technical planning for the development of new CIs and CPCIs should be accomplished in parallel with the system engineering analyses being performed to develop the Type B specifications. This activity normally involves conducting preliminary studies of hardware or software design for each item, which should be carried out during this phase in sufficient depth to provide a basis for (1) evaluating the impact and feasibility of detailed performance requirements as they are formulated, and (2) determining schedules and resources needed for each item's development during the next phase. Internal test planning is included in the development plans. Separate, preliminary plans for CI and CPCI qualification should be developed concurrently and in coordination with test requirements being documented in Section 4 of the B-type specifications.

d. System integration and test. Significant continuing activities at the system level are concerned with requirements and plans in the areas of system and system segment interfaces, site installation and checkout, and system development test and evaluation (DT&E). By the end of this phase, functional definitions of all system and inter-segment interfaces should be completed and incorporated into the system specification, together with all definitions at lower levels which exist as predetermined constraints (cf. 2.4.1 above, Block 3.1b). Following the completion and verification of performance, design, and interface requirements in Section 3, Section 4 must be completed to specify methods and levels of DT&E to be employed in verifying that those requirements are met. As a part of these activities, associated plans are prepared for: interface control during the development phase (primarily for equipment and facilities); site equipment installation; and system DT&E

The SDR is conducted before this stage ends to review requirements of the updated system specification, specifications of requirements allocated to configuration items, and the contractor's accomplishment of system engineering management objectives. System engineering studies should have been performed as required by the SOW--and by the nature of questions encountered during progress of the work--, either separately or as inherent parts of the activities described above.

At the system level, the emphasis at SDR is placed on adequate coverage and assessment of system/system program characteristics in such areas as integrated logistic support, standardization, growth capabilities, life cycle costs, and other special topics listed in Appendix B of MIL-STD-1521A, as applicable to the given program. Objectives are similar to those of the preceding SRR, but with attention at this time to comprehensive coverage, completeness, and integrity in the light of lower-level studies of requirements allocated to the system elements. Information required in final form pertaining to the specification tree and CI lists (in paras. 3.1.4 and 3.7 of the system specification) should be fully complete by SDR, including specific identifications of all equipment and computer programs required for support as well as for mission operations.

At the item level, a significant purpose of SDR is to review the specifications proposed to constitute the system allocated baseline--for format, content, technical integrity, traceability to system mission/support requirements, and correlation of requirements across the full set of items. The general emphasis of this review is on verifying that the contractor has, in fact, successfully translated system requirements into individually-defined sets of requirements for the system hardware and software elements. Critical requirements to be examined for data processing and special communications equipment items relate to speeds, capacities, compatibility with the projected nature and structure of system computer programs, and secondary characteristics in such areas as operability, electromagnetic compatibility, reliability, and maintainability/availability. For computer programs, particular attention is typically needed to examining (a) system engineering documentation generated in the process of deriving requirements for the mission/operational CPCI(s)--together with related requirements for operational personnel and interfacing equipment characteristics (e.g., detailed operating characteristics and/or layouts of displays and manual input devices)--, and (b) technical integrity and completeness of the Type B5 specifications themselves.*

2.5.3 Evaluation and Decision

This final period of the validation phase is devoted to reviewing and evaluating contractor products, updating program planning documents, and accomplishing related actions required for the milestone II decision.

Contractor products to be evaluated consist of technical and planning data items delivered against the validation phase CDRL. The total package of data submitted by each contractor should include items in the following categories:

--Updated/expanded system specification--in the form of an ECP package, containing specification change notices (SCNs) covering exact proposed page changes to the specification.

--Allocated baseline documents--the full set of development specifications (or their equivalent; see 2.5.2.2,a above) for hardware, software, and facilities items.

--System engineering documentation--reports of functional analyses, requirements allocations, trade studies, human factors engineering studies, program risk analyses, computer program sizing and timing studies, personnel and training requirements, et al.

*The evaluation of B-type specifications accomplished at SDR is preliminary, resulting immediately in directions to the contractor for corrections/improvements to be incorporated prior to their submittal at the end of this period. Full evaluation of the specifications as a basis for PO authentication (and baselining for subsequent configuration control) is accomplished via in-house specification team review procedures following that submittal. A further discussion of factors to be considered in evaluating the Type B5 specifications is provided in another guidebook of this series (see ref.18, para. 2.1).

--Management plans for full-scale development--system engineering management plan (SEMP), computer program development plan (CPDP), test plans, equipment/site installation plan, work breakdown structure, and others as required by the RFP and/or validation phase CDRL (for a "shopping list" of these plans, see paragraph 3-18, AFSCP 800-3).

--Contractor cost information and recommended inputs to the full-scale development phase SOW and CDRL.

Those items should be evaluated individually against requirements established for each item in the contract and/or RFP. The system specification is evaluated for continued adequacy in specifying Air Force operational needs for the system. Each contractor's proposed changes should consist, primarily, of expanded definitions of the system segment configuration--i.e., in the form of CI/CPCI lists, requirements allocations to the items, and schematic block diagrams depicting functional arrangements of the hardware and software assemblies. Additionally, the contractor's SCNs should normally include proposed clarifications and expansions in other areas--e.g., design and construction standards, inter-segment interfaces, and test requirements (Section 4)--which fully reflect his proposed approach to system hardware and software implementation.

However, the important overall assessment to be made at this point is whether that total collection of technical, management, and cost information is sufficiently sound and realistic to warrant progression into the next phase of the system program. Assuming that the system specification is judged to be adequate and complete, the burden of that overall assessment now rests on determining that (a) the allocations of system requirements to hardware and software elements have been soundly accomplished, (b) the allocated baseline documents are adequate, both individually and as a set, to govern actual acquisition of the system elements, and (c) the contractor's management plans and cost estimates for full-scale development represent, in fact, serious and realistic planning based on identified needs of this program.

SECTION 3. ISSUES AND PROBLEM AREAS

The system specification is not intended to be a "stand-alone" document. As prescribed in the current standards, its content reflects established conventions based on intended functions of the system specification in relation to the many other documents that are typically generated and used in the course of a typical system program. Generally, specification types are distinguished from one another--and from such other documents as plans, manuals, reports, etc.--on the basis of such factors as scope, nature of technical and/or management content, phasing, sources, and intended uses. However, the structure of documents in a large system program tends to be sufficiently complex and variable that those distinctions are not always obvious. Purposes of the discussions provided in this section are to summarize intended functions of the system specification, as those are stated or implied in existing standards, and to identify a few problem areas which have proved to be prominent sources of difficulty and/or disagreement.

3.1 Summary of System Specification Functions

Traditionally, specifications are documents which define the required characteristics of items, processes, or materials to be developed or produced and delivered by a contractor. The specification is normally referenced in, and functions as a part of, a contract statement of work. While the specification types, forms, and uses prescribed in current military standards conform generally to traditional Government and industry practices, they have been influenced significantly by considerations derived from the special circumstances of system acquisition programs. It is also pertinent that the standards we have today--i.e., those contained in MIL-S-83490 and MIL-STD-490--are largely based on Air Force systems management policies that were in effect during the early and mid-1960s. The standards have not changed; but some questions do arise as a result of continuing, substantial changes which have occurred since that time in the policies and circumstances of system acquisitions.

The structure of (program-peculiar) specifications as a whole in a system program consists of (a) one specification for the system, written primarily at the performance level, and (b) one specification for each procurable end item of materiel. The basic principle which differentiates the system specification from item-level specifications was once expressed in the following terms:

> "The concept of the uniform specification program (USP) is based on the fact that systems/equipment are not procured by single identifiable systems but rather by separate end items of contractor peculiar items, Air Force Supply Federal Stock, and commercial 'off-the-shelf' items. It is recognized that an end-item specification program must be correlated with weapon-system procurement programs and methods."*

The direct and significant implication of that statement is that: Contractors can be made fully responsible for the development and supply of end items, in accordance with item-level specifications which are made a part of their contracts. *But contractors are not obligated to see that the system meets Air Force objectives; the responsibility for compliance with the system specification as a whole remains with the Air Force procuring activity.* Further implications of that principle are amplified in the following summaries of system- vs. item-level specification functions during the course of a system program.

3.1.1 Relations of Technical to Management Factors

The focal products of contractors to be specified, managed, and accepted during a system program consist of identified items of hardware and software--generally referred to as configuration items. A few of the established rules which relate to questions at hand are as follows:

a. Although special provisions are made for some hardware components ("critical items") which may be specified separately, the specification "tree"

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*From Chapter 1 of the former AFSC Manual 375-1, Configuration Management During the Acquisition Phase, dated 1 June 1962. The uniform specification program referred to is the effort which led to the structure now standardized in MIL-S-83490 and MIL-STD-490. Prior to that effort, there was a proliferation of specifications with diverse titles, formats, coverage, and uses.

consists basically of only two levels--namely: (1) the system level and (2) the item level. The form of a specification tree to be provided in the system specification (in para. 3.1.4) is illustrated in Figure 3-1.

b. That specification structure must be capable of covering the acquisition of all hardware and software needed in the system. However, it does not have an obvious, one-to-one correspondence with the hierarchy of hardware/software assemblies which is typically generated as a result of engineering analysis and design. Figure 3-2 illustrates a (partial) sample of the latter, which represents the immediate technical product of conceptual and validation phase analyses described previously. Essential "correlation" of that breakdown with the specification tree is nevertheless achieved by virtue of the facts that:

(1) The top three levels represented in this diagram are levels of assembly to be defined directly in the system specification.

(2) Assemblies at the fourth level may all be identified and specified as separate CIs (except that the Computer Programs block shown in this sample would be likely to consist of separate CPCIs at the next lower level).

(3) Assemblies at lower levels may be specified either as separate CIs or as components of the larger CIs into which they assemble. For example, the Power Supply (fifth level) could be identified as a separate CI because it is to be Government-furnished or procured from a vendor.

c. Thus, the CI concept functions to define a contracting level, somewhat independently of the technical/assembly relationships of the items specified. That is, the designation of a "CI" applied to a given assembly of hardware or software components, of whatever size or complexity, defines a level of management as between the procuring activity and contractor which involves, for example: one specification, one set of technical design reviews and configuration audits, one test (qualification) program, and

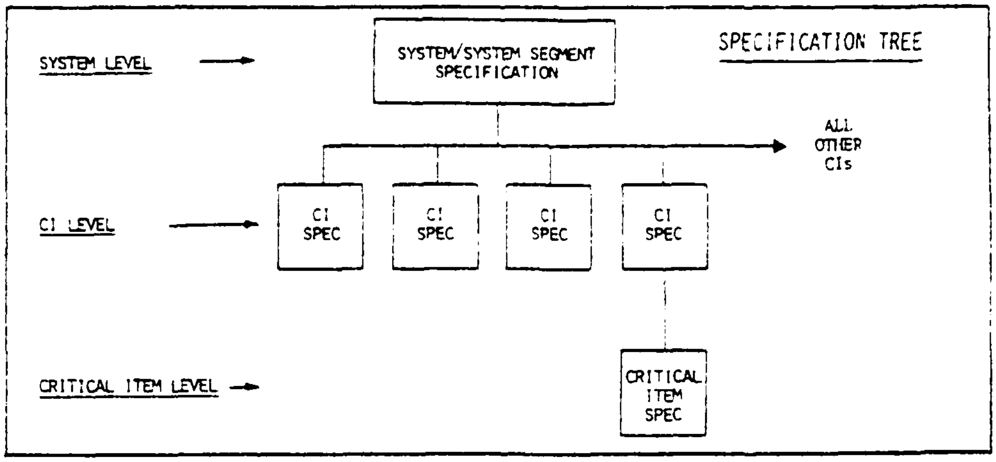

Figure 3-1. Specification Tree.

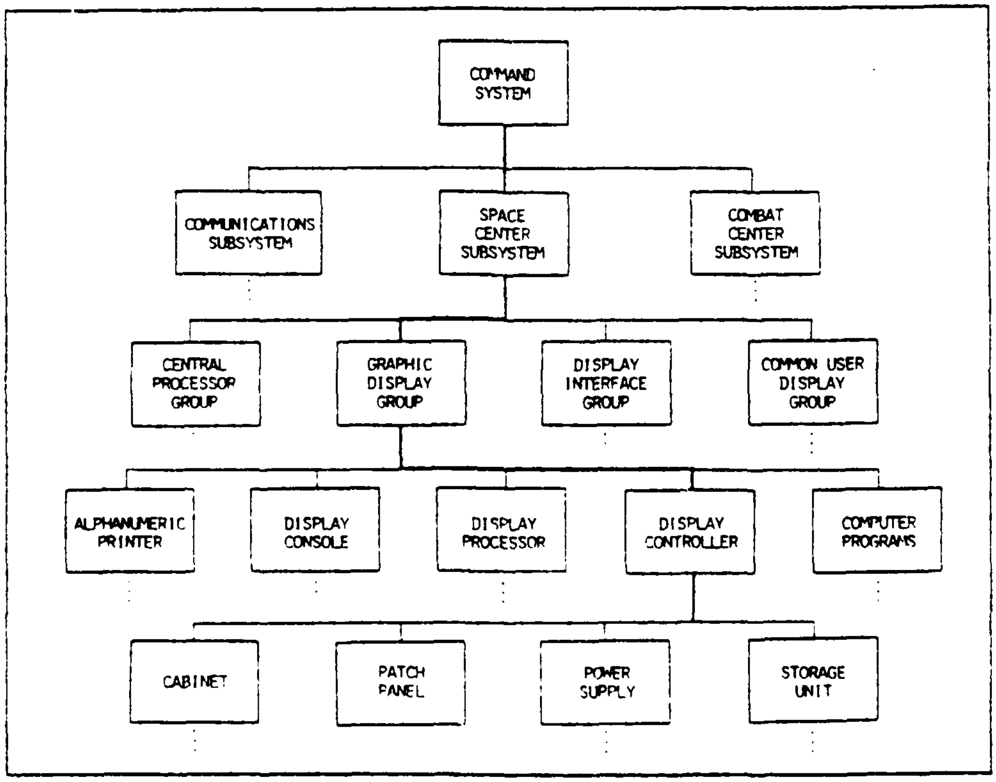

Figure 3-2. Generation Breakdown (also, Assembly Tree, Installation Tree).

one set of support documentation. It is the level of delivery and acceptance, accountability, and provisioning for logistic support.

d. In the framework of that established model, assurance that requirements for integrated performance of assemblies at the functional area/system segment/system levels will be met rests heavily on provisions for controlling interfaces among the CIs. "Interface control" is most often thought of as a prominent activity of participating contractors, carried out principally during full-scale development. However, the only real control contractors can exercise at that stage is over their in-process designs of equipment items at the *product* level--to meet requirements and constraints established in their contractual, allocated-baseline specifications. Actually, the PO accepts primary responsibility for interface compatibility among CIs at the time the CI performance (allocated baseline) specifications are approved and placed on full-scale development contracts. The assumption is that measures have already been taken--prior to and during the validation phase--to assure that interface requirements were systematically and comprehensively identified, analyzed, allocated to CIs, and properly incorporated into the CI specifications.

3.1.2 Summary of System Specification Functions

As indicated above, the system specification is a document which governs, primarily, the PO itself. It does have some uses as a contracting instrument, however, within the established framework of system acquisition management procedures. The following summary includes mention of those, together with notes to indicate their recognized limitations.

a. Program Requirements Baseline. The system specification begins to function at the time it is initially prepared, coordinated, and approved by HQ USAF as a part of the PO's "charter" for pursuing the program. It defines the technical portion of the program requirements baseline, which also includes the documented operational concept, logistics concept, and cost estimates. Significant changes in broad objectives defined in those documents, later in the program, require HQ USAF review and approval.

b. Functional Baseline. As described above (2.5.1), the system specification is established as the functional baseline for formal configuration control by the Program Office CCB by the time it is issued with validation phase RFPs. Probably its major single function in the life of the program is to serve, during that phase, as the basis for program planning and the derivation of lower-level requirements for system personnel, hardware, software, and facilities.* But, since it continues to serve that and other significant functions identified below, it is systematically controlled thereafter and maintained to reflect the impact of all approved changes.

c. System Test and Acceptance. While contractors normally provide substantial support, the planning and conduct of system DT&E is a Program Office responsibility. System DT&E is planned against requirements stated in Section 4 of the system specification and conducted to verify that the integrated collection of system elements will in fact meet the performance/design and interface requirements set forth in Section 3. Acceptance of the system by the operational command is based principally on successful accomplishment of system DT&E.

d. Total System Procurement. The assertion has been made that the Air Force should acquire each system "as an entity" from a single contractor, using the system specification as the contractual compliance document. Program Managers do have the flexibility and obligation to tailor each program according to its needs; and there are understandable motives to depart from the practice of procuring solely at the CI level (see 3.2 herein). However, the system specification is not designed for that application. Some of the pertinent considerations are mentioned elsewhere in this discussion. Additionally:

(1) The accepted acquisition management standards--throughout such areas as configuration management, design reviews, test programs, and acceptance --are based, by and large, on the established differentiations of

*At one time in the history of system programs, that was the only real function of a system-level specification. After that initial use, it was often simply replaced by the other, derived documents.

PO and contractor responsibilities for the system as a whole vs. configuration (end) items. Current standards associated with AFR 800-series procedures provide little or no guidance or support for a total system procurement.

(2) Figure 3-3 presents a summary overview of system specification functions in governing both the on-going system program and the system itself as a complex end product. As indicated, elements of the resulting system are acquired individually through the use of lower-level specifications. However, some of those essential elements of the *total* system are ones which a prime contractor to the PO cannot furnish, and which the PO itself can control only within limits of its designated Air Force authority. As notable examples:

(3) The PO can control requirements for system facilities that are documented in Type B4 specifications. But actual facilities acquisition

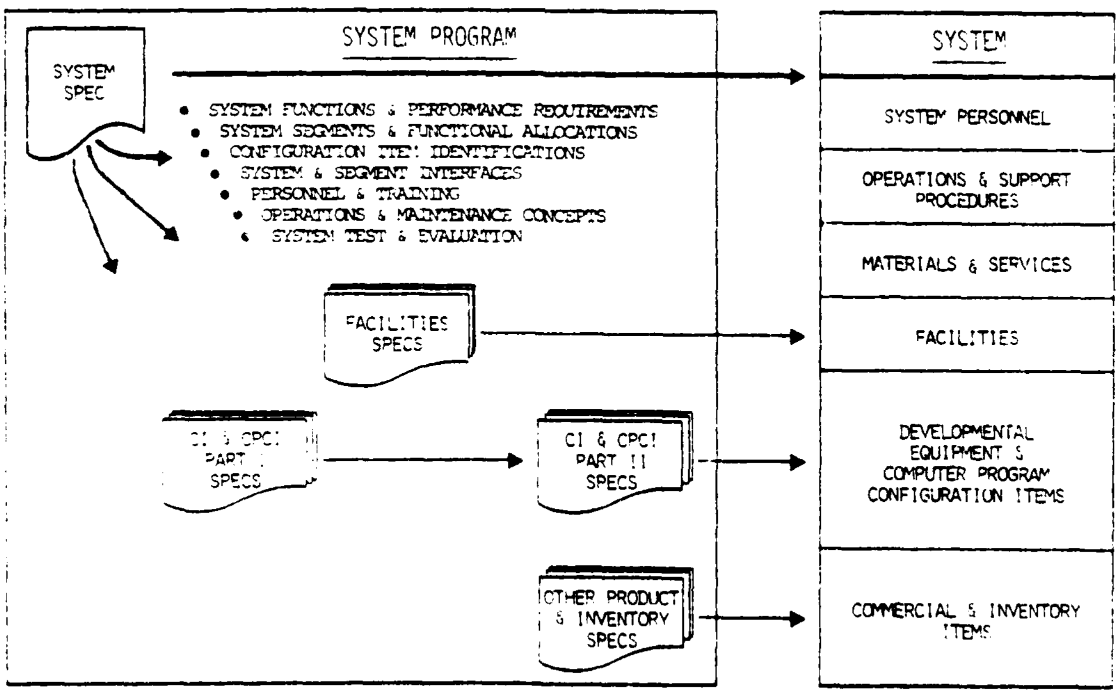

Figure 3-3. Summary of System Specification Coverage and Functions.

(military construction program) must be accomplished by the Army Corps of Engineers or Naval Facilities Command (NAVFAC) through contracts administered by those agencies.

([illegible]) The PO can also control the development and dissemination of documents which detail requirements for the selection and training of system personnel. However: manpower allocations must be made by HQ USAF; and personnel are actually selected, trained, and assigned by ATC and the operational command. --This is by no means a negligible consideration. Deficiencies in trained personnel have been known to cause system failures.

e. Item Procurement. The system specification is classed as a "general" specification, covering characteristics which are common to an identified class of items (in this case, items classed as parts of a given system), whereas the specification for a single item is classed as a "detail" specification. In that role, it does normally serve as a supplement to, and/or as a part of, the contractor's procurement specifications for end items. Thus, in the detail specification placed on contract for procurement of the item, some requirements may be stated--in the item specification itself--by reference to appropriate paragraphs of the system specification.* However, the PO must take care to assure that the referenced requirements are identified specifically, and that they do not conflict with other provisions expressed directly in the detail specification. Orders of precedence listed in the SOW and/or specifications notwithstanding, contractors must normally observe lower-level requirements whenever they conflict with requirements stated at more general levels or in higher-level specifications.

f. Contractor Services. The process by which contractors derive program plans and lower-level requirements for system elements from the initial system specification was outlined in 2.5.2 above. The system specification

*For examples, see (a) MIL-STD-490, paragraph 20.3.3.6 (specifying "Safety" for a prime equipment item) and (b) MIL-STD-483, Notice 2, paragraph 60.5.3.4 (specifying "Human Performance" for a CPCI). The latter happens to be an unsound example, incidentally, but for reasons unrelated to the present discussion; see reference 18, paragraph 3.12.

functions during that phase as a compliance document in the sense that contractors are bound to be consistent with its requirements, but not in the sense--normal to contract specifications--that the contractors must deliver a set of validation phase products which meet those requirements (namely, the system itself). At that stage, contractor products are defined directly in the SOW and CDRL and accepted or rejected by the PO on the basis of compliance with those documents. During full-scale development, the system specification is normally placed on contract, together with item-level specifications and SOW requirements for contractor services in such areas as configuration management, interface control, system installation/integration, and support of system DT&E. Again, however: while contractors are now fully responsible for meeting requirements of item-level specifications, the system specification continues to function primarily as a reference source of criteria against which to judge the acceptability of their services--not as a direct definition of characteristics to be achieved by their deliverable products.

3.2 Trends, and Questions to be Explored

It was mentioned earlier that the principles upon which the established structure and roles of specifications are based were derived in the context of system acquisition management policies and circumstances which existed in the early 1960s. Some of the problems encountered in recent years can be traced to changes in the latter which have not been accompanied by corresponding revisions or clarifications of the principles and their applicability. Among the many and varied changes/trends, two are noted below which have been associated prominently with questions about functions of the system specification.

PO Manpower. It is an in-built assumption of established procedures that the PO will have trained and experienced personnel, in adequate numbers over the range of significant technical and support management disciplines, to "stay on top" of a system program throughout its duration. However, the numbers of trained civilian and military personnel available (and authorized) for assignment to PO positions have decreased markedly over the years. With limited resources, pressures have increased to shift a greater portion of the total burden to contractors. POs at ESD have in fact taken measures along that line, in two forms: (a) of acquiring more direct support to the PO from system engineering contractors; and (b) making more use of the system specification instead of allocated baseline specifications as the primary technical requirements instrument to govern full-scale development. Although devices of necessity rather than choice, both of those have been reported to help in alleviating the pressure. As indicated in the preceding discussion of system specification functions (3.1), the latter represents a relatively uncharted approach in the light of established principles and practice; and its use is necessarily limited to something less than the total system. However, additional reasons which suggest that it should perhaps be further explored are discussed below.

Existing Items. The use of existing commercial and Government-inventory items has shown a steady increase, as a result of both current policy and increased availability of general-purpose components, to the point that they now often constitute major portions of a total electronic system. However, while the specification structure as such has always included provisions for those, most of the substantive guidance for managing system contracts applies to items of new development. The differences in indicated (and practicable) management procedures are sufficiently extensive that care has been taken in some programs to avoid designating the commercial elements as "configuration items", largely for the reasons that: their commercial specifications are typically not adequate or usable for configuration control at either the allocated or product baseline levels, due to obstacles posed by considerations of ownership and data rights as well as content; and standard procedures for managing technical design reviews, qualification testing, and configuration audits are not applicable.

The fact that Type B specifications are not written for commercial items implies that special attention must be given in the system specification--i.e. in the initial issue--to maintainability and related support requirements to govern the selection and acceptability of those items. The nature of such requirements must be carefully tailored to operational and support concepts for each system with respect to relevant factors of geographic location(s), deployment, and environment.

3.2.1 Illustrative Problem Case

Figure 3-4 contains a diagram based on the arrangement of principal equipment items proposed by one contractor to meet the requirements of a system segment specification. In this sample, individual items identified within each of the four sets labeled "functional groups" are all commercial, including two or three requiring some degree of modification for this intended use. Computer programs (not shown) are associated with each of the functional groups, consisting of both operational and support items. In the segment as a whole, the only major items of new development are the operational CPCIs.

Referring to the model process described for the validation phase in 2.5 above, this diagram illustrates a situation which is likely to exist at about the time of SRR, after the contractor has analyzed segment-level requirements, allocated those to functional areas, and identified principal items of hardware

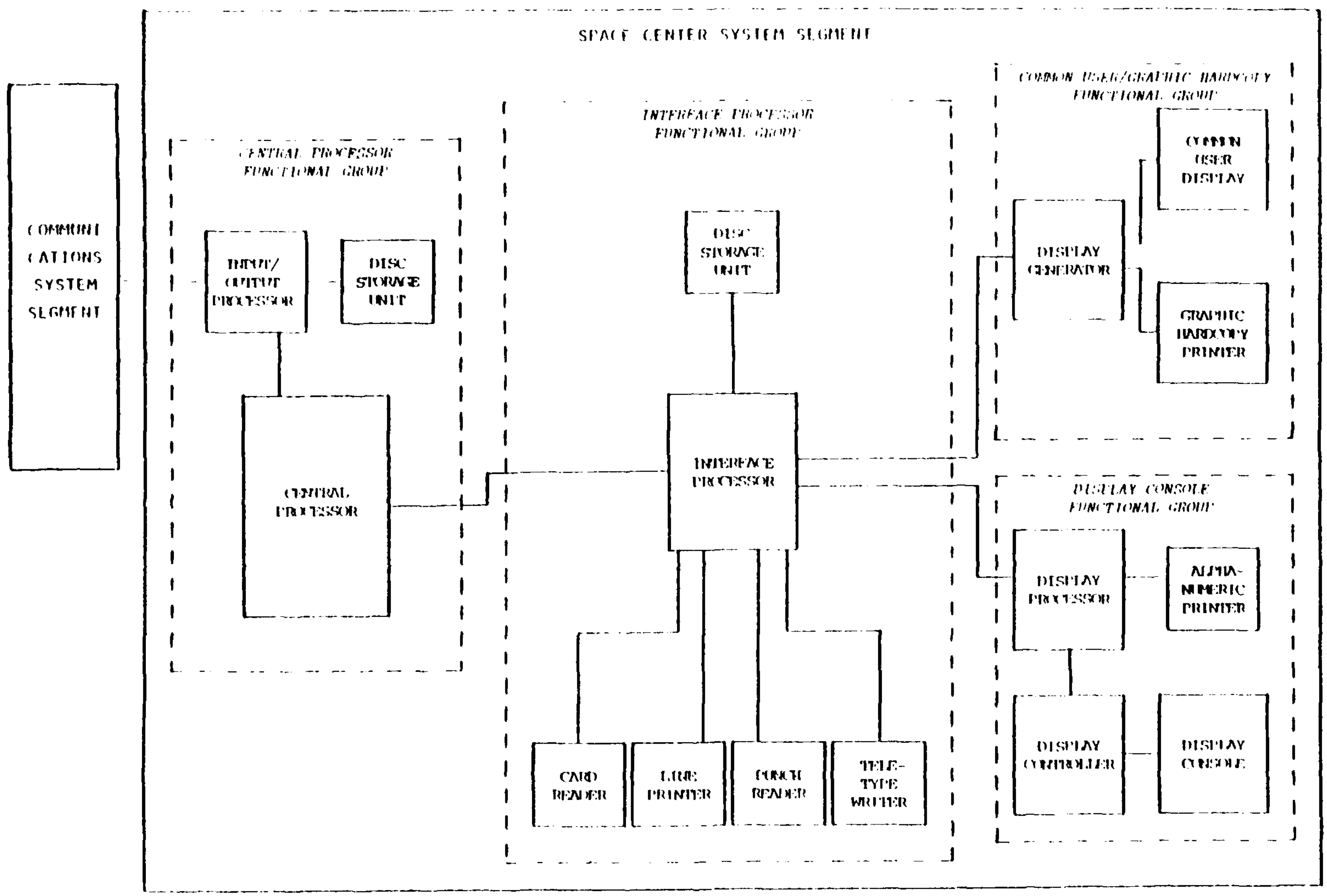

Figure 3-4. Sample Arrangement of Major Equipment Items in a System Segment.

and software within each functional area. The preponderance of commercial items is clearly in line with objectives expressed in the SOW; and it does have the basic advantage that significant factors of performance and cost are relatively "proven" as compared with items of new development. At the same time, viewed in the light of accepted acquisition management practices, the situation poses to the PO certain novel questions and problems of its own:

- If those items are to be listed in the expanded system specification and their commercial "specifications" accepted and approved, the PO must perform the considerable task of verifying independently the item selections, performance potentials, and interface compatibilities before incorporating them into the full-scale development contract.

- The individual items shown in this diagram--computers, consoles/displays, and related equipment--are in fact properly identified as "configuration items", to the degree that basic criteria for CI identification and selection apply at all to this total segment configuration. The significant consideration is that each is a level of assembly separately manufactured and documented as such, and in many cases by separate original suppliers/contractors.

- Nevertheless, there will be little or no equipment development for the PO to monitor and manage, during full-scale development, at the normal configuration item level. Notably, there will be no technical design reviews or qualification test programs for the commercial items as a basis for their audit and acceptance.

- When contractors are responsible for CIs of new development, they share a portion of the total program risk. But one net result of this case, carried to its logical conclusion, is that essentially all of the risk (i.e., for system equipment) is shifted to the PO, since new development is now limited to complex assemblies above the level of CIs.

3.2.2 Proposed Solutions

The situation described above has existed in several programs, although with a number of variations in relevant circumstances. As indicated earlier, ready-made solutions are not prescribed in the current standards; and this guidebook does not have a simple solution to recommend. A PO faced with those problems is largely "on its own"--although, to avoid problems that could be even worse, any novel approach must take full account of basic principles which the established standards and practice do reflect. Some considerations are summarized below relating to each of three approaches that have been tried or proposed in recent programs. At this point in time, all of these need further study to clarify their potentials and limitations for general use.

Two of the three solutions referred to were proposed in the program on which the diagram shown in Figure 3-4 is based. The other (the first discussed below) has been implemented in other programs.

a. One PO has adopted the approach of using the system specification as the sole contracting instrument to govern development of all system hardware and software. Although subject to limitations discussed previously, there are indications that this device can be made to work in some cases. The cases known so far are ones in which the system happens to be atypical, in that it does consist principally of one large prime equipment item (a "one-of-a-kind" surveillance radar). The purpose, and reported real result, is to reduce demands on PO manpower by placing full responsibility onto the system contractor for all management at the CI level during full-scale development. This means that the PO has correspondingly less control at that level while the development is in progress. Implications which this PO has recognized and accepted include the following:

   - The contract specifies that normal CI-level requirements (for developmental items) are to be observed, in a normal phasing sequence, in such areas as development specifications, technical design reviews, qualification test programs, and product specifications--but, wholly managed and controlled by the prime contractor from the time of contract award through successful completion of system DT&E. The system testing is also managed/conducted by the contractor, but witnessed and approved/accepted by the PO (as the qualification testing would normally be for a CI).

- Although the PO may act as an observer at intermediate CI-level events and receive information copies of documents, it does not accept or control CI-level products until system DT&E is completed. At that end point of the program, the PO then holds a physical configuration audit (PCA) to examine and accept the CIs, their specifications, and other documentation.

- Configuration management procedures are adjusted accordingly. Throughout the period of initial acquisition, the PO's configuration control is confined to the functional baseline level. The prime contractor may report to the PO changes to CI/CPCI specifications which he has baselined for internal control, but in the form of "record-only" ECPs.

b. The system on which the diagram shown in Figure 3-4 is based was substantially larger and more complex than the case just described; and computer programs were a more prominent part of the total acquisition. The plan to manage computer programs as individual CPCIs, in accordance with normal practice, was not in question. With respect to equipment, however, the questions and problems outlined in 3.2.1 above led members of the PO to search for an alternative approach. Of two alternatives proposed, the one adopted (in some haste) was later reported by participants to have created more problems than it solved. That concept is outlined as follows:

  - Each of the complete assemblies illustrated as a "functional group" in Figure 3-4 was designated as a prime item of new development. Equipment CIs identified by specific numbers and nomenclature in the system (segment) specification tree and CI list were confined to those prime items.

- The segment contractor was required to prepare a Type B1 specification for each of the functional groups, to be followed later by a Type C1b (product fabrication) specification. Following acceptance, they would become items in the Air Force inventory at that level, identified as items manufactured by the PO's segment contractor.

- Development and test plans for full-scale development provided for design reviews, qualification testing, and configuration audits at the functional group (prime item) level.

Some of the problems encountered in the course of implementing that plan resulted from difficulties experienced by the contractor in preparing the specifications, particularly at the product fabrication level. Guidelines for handling the commercial items (now identified as commercial *components*) were never clearly formulated; and they proved to be matters of disagreement with respect to a range of questions having to do with the use of commercial documentation, quality/forms (and even availability) of engineering drawings, test data and special test support equipment for the commercial components, and others. One significant factor which tended to exacerbate problems was the fact that the requirement for the contractor to assume these responsibilities did not emerge until after the contract had started, and after the contractor to the PO had already negotiated subcontracts and purchase agreements with original equipment manufacturers.

c. The alternative which was proposed but discarded in favor of that just described is not known to have been implemented in an actual program. However, there are reasons to believe it would have been a better course to follow. The concept derived in part from the fact that a validation phase had not been conducted; and there was early evidence that the system specification--which consisted of one general volume and separate volumes for the system segments--had suffered from an absence of both (1) thorough system engineering analysis and verification, and (2) specific expansions and refinements by the successful segment contractors to reflect their intended design approaches. Based primarily on discrepancies in the latter area, combined with the considerations described in 3.2.1 above, this proposal outlined the following principal steps:

- The contractor's first task is to expand the system segment specification to define functional areas, allocate requirements to those, and verify consistency with the segment requirements as a whole. Within each functional area, requirements are further allocated to computer programs and equipment. However, while the CPCIs are identified specifically, requirements allocated to equipment are specified for the group of equipment elements in each functional area as a whole.

- Equipment items comprising each functional group are identified at this time by generic names only. The PO neither approves their selection nor accepts their individual (commercial) specifications.

- Taking into account the fact that Type B specifications will not exist to provide further detailed performance/design/interface requirements at the item level, the definitions of requirements provided directly in the system segment specification itself must be comparable in scope and level to the content of a Type B1 specification for each functional group as a whole.

- Once completed and approved with those changes, the system segment specification is then placed on contract to govern the contractor's development of those functional groups. Development and test plans are prepared to schedule design reviews, testing, and configuration audits for each functional group. Acceptance of individual equipment items will occur when PCAs are completed successfully for the functional groups. The system segment specification is *then* updated to incorporate specific identification of the commercial items. After that time, Air Force management may then revert to the item level for purposes of logistic support and accountability.

3.3 Program Risks

A "program risk" is a factor which creates a likelihood that system performance or supportability objectives may not be achieved within the acceptable range of projected program costs and schedules. Since it is characteristic of system programs that they are initiated and carried out to develop new capabilities which take advantage of the latest available technology, the risks which tend to receive most visibility and attention are those of a technical nature. Following a number of experiences in early system programs which attempted to incorporate scheduled "technological breakthroughs",* it has long been a policy within the DoD not to permit a system program to proceed into full-scale engineering development until assurance exists that technical risks have been minimized--meaning, specifically, that subsequent effort must be a matter of straightforward engineering design and development without significant dependence on further invention or scientific advancements. Current policies also emphasize early identification and reduction of related risks associated with the system operability and performance in its intended military environment.

Thus, in the context of problems encountered during full-scale development and later phases of system programs with embedded computer resources in recent years, there has been a widespread tendency to assume that the computer resources, especially computer programs, constitute areas of high technical risk. Hence, steps to improve the software base of technology and abilities of Program Offices to monitor and evaluate the technical aspects of software development have been prominent among lines of activity taken to alleviate the problems. Those efforts are clearly needed and appropriate, to a degree. However, the risks (known or unknown at the time) which have actually materialized into program problems or failures indicate that increased attention is also needed to a number of related, other factors in the system acquisition program as a whole.

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*Notable examples during the 1950s were a nuclear-powered aircraft (System 125A) and the outer-atmosphere vehicle, Dynasoar.

Considering the complexity of large system programs, failures can result from deficiencies in any one or more of many areas. To be successful, the Program Office must take steps to assure that adequate attention is paid to minimizing risks across the whole spectrum of potential pitfalls. That is to say, concentration on eliminating any one risk factor, however significant, is "necessary, but not necessarily sufficient". However, the following paragraphs discuss a few risk factors associated with the system specification which clearly merit far more concentrated attention than they have typically been given.

Based on many surveys, there is a wealth of evidence that the most pervasive single, technical source of difficulties in system programs is a matter of deficiencies in the amount and quality of *system engineering* effort applied during early phases to develop, document, and verify adequate definitions of requirements. This deficiency has been recognized as being a chronic characteristic of system programs in general, for decades. Awareness of its effects on problems with embedded software are evidenced in such comments (by system/software contractors) as the following:*

> "...initial requirements were not critically analyzed and verified through a formal program of advanced development or system definition."

> "...lack of thorough analysis and validation of requirements."

> "...many technical, cost, and schedule problems can be traced to inadequately defined requirements."

> "Often the difference between success or failure of a large software project lies in the consistency and completeness with which the system requirements have been specified..."

> "Much more effort and money should be expended on the preparation of good development specifications... The Government should be an active participant in the technical effort leading to these specifications."

*Selected quotations drawn from the DoD Weapon Systems Software Management Study (ref. 17).

This key factor accounts for the emphasis placed above, in the discussion of system specification development (Section 2), on thorough analysis of system requirements during the conceptual phase, and on employment of the validation phase for the primary purpose of completing/expanding the definitions of system and software requirements. Those objectives are consistent with current Air Force/DoD policies, although it must be recognized that there has been a dearth of guidance or support for their implementation in the manner described, specifically for electronic systems/computer resources.

One possible source of confusion lies in the label "validation phase" itself, which tends to highlight the importance of such activites as prototype demonstration and hardware proofing. Those activites are indeed emphasized within the DoD for major defense systems in general. However, it is also clear that that emphasis is based primarily on reference to systems in which the focal developmental efforts and technical risks are associated with major new prime items of military equipment--such as supersonic bombers, cruise missiles, ballistic/antiballistic missiles, nuclear submarines, or tactical aircraft. The early demonstration principle is still only the "means to an end"; its function is to support the mainline objective of minimizing program risks before embarking on a full-scale development.

Thus, in tailoring his program according to its needs, it is incumbent on the electronic system Program Manager to examine the applicability of those concepts in the light of their significance to his actual circumstances. While there may be exceptions, the overwhelming weight of electronic systems experience dictates that in most cases *he should--indeed, must--conduct a validation phase, but will rarely have good reason to require prototype demonstration/hardware proofing tasks as significant parts of that effort.* A few of the relevant considerations are summarized below.

a. The validation phase task of contractors to analyze and complete the system specification represents an important step in assuring that the specification is a sound instrument. Even when it may have had the benefit of good system engineering study and verification during the conceptual phase, there is still the need to assure that its requirements are compatible with design approaches proposed as being known and feasible by the implementing contractor(s).

b. Equally important in promoting the PO's confidence that contractors really understand the requirements and their implications are the results of associated implementing tasks during the validation phase--of identifying items of hardware and software, developing item-level performance specifications, analyzing development and support requirements, and preparing comprehensive plans for full-scale development. If there is any single factor that can be pointed to as having the highest priority for embedded software, specifically, it is clearly in the area of improved development specifications for operational computer programs.

c. Major new prime items of equipment are not normally developed as part of an electronic system program. Predominantly, the hardware portions of the system consist of digital computing equipment, communications devices, and consoles. While some of the elements may be newly-developed for the given program, they are largely commercial off-the-shelf or consist of commercial components arranged in a tailored configuration. The risks, in practice, tend to be matters of proper selection and assembly of those items such that the equipment configuration as a whole, once installed, will meet system requirements with respect to types of data processing, speeds, capacities, reliability, and supportability.

d. The prominent items of new development for most electronic systems tend to be operational (mission, or applications) computer programs. There are some known examples in which certain requirements stated in the system specification have raised questions of technical feasibility--and/or technical competence of the contractor--that might conceivably be resolved or clarified by means of "software proofing" or early demonstration. However:

   (1) More often than not, those questions should normally have been examined and resolved before completing the initial system specification.

Most of the known instances (e.g., questionably-stringent requirements for data security) are ones which imply long-term study, and are by no means confined to software.

(2) Unless there happens to be a specific objective which is known to be exceptionally important, requirements for early demonstration as part of the validation phase should be avoided. In the competitive environment, contractors are likely to channel their principal and best resources into that activity; and the other, typically higher priority objectives of comprehensive requirements and program definition will suffer accordingly.

(3) Experience clearly indicates that the PO's most urgent source of concern, normally, is whether the contractor will be able to deliver a total, integrated collection of the system software, on time and within estimated costs, which really meets the full range of system operational and support requirements. No case has yet been reported of a system program failure caused by limitations in software state-of-the-art as such. The plethora of actual problems encountered--i.e., the real-life risks which have so often been taken and lost--are matters of inadequate requirements definition, planning, and management.

APPENDIX A. SYSTEM SPECIFICATION PREPARATION

Most of the content of this appendix is drawn from a system specification preparation guide which was developed at AFSC's Space Division (SD). The material is used herein with the permission of its author, Mr. Ernest Wade of The Aerospace Corporation, to whom this author is also indebted for consultation in adapting it for this use. While that guide emphasizes requirements which are important in space systems, it also contains information which is both generally useful and potentially helpful in tailoring the MIL-STD-490 instructions to other classes of systems.

The principal sources of general requirements for preparing a system specification are Appendix I of MIL-STD-490 and Appendix III of MIL-STD-483 (USAF). The instructions contained in those sources set forth minimum requirements which are written at a very general level to cover all classes of military systems, and to serve the generally-useful purpose of enforcing a base of standard practice. However, it has been the common experience that a substantial amount of additional direction and guidance is needed to support their effective use in any given case.

Basic sections of this guidebook have emphasized the fundamental problem of developing and verifying an adequate foundation of requirements data to provide the essential technical content of a good system specification. Beyond that, however, the process of translating the input information into statements of requirements which are consistent with sound specification practices is a significant task in itself, particularly when combined with typical needs to adjust the specification format and emphasis to a given class of systems.

A committee which was formed to investigate problems encountered with one system specification at ESD recommended recently that a new pamphlet be developed as a guide to the specification preparation for electronic systems. While that topic is clearly within the scope of subjects which deserve coverage in this guidebook, it is recognized that the task as a whole demands longer time and a broader base of resources than have been allocated to preparation of this initial issue. Thus, the material presented below is limited to available and relevant information which may prove useful as a starting point for such a longer-term effort.

Organization and Content

To avoid the use of a dual numbering system, paragraphs in the remainder of this appendix are identified by the section/paragraph numbers and titles specified for the system specification in MIL-STD-490. For reference, an outline of that specification structure as a whole is reproduced in Figure A-1. (Note: the coverage provided herein extends only through Section 3.)

Guidance material presented in the following pages is organized around successive, relatively short groups of related specification paragraphs. The material associated with each group consists of information derived from three sources: (a) content of the basic SD guide; (b) content of a "model specification" which was printed originally as an appendix to the SD guide; and (c) comments by the author of this SAM guidebook on significance of selected topics to electronic systems. For ease of ready identification by readers, those three kinds of content are presented in different type style or format, as illustrated in the explanations provided below:

Paragraph x.x, Basic SD Guidebook. This element, taken from Mr. Wade's guidebook, incorporates instructions extracted from MIL-STD-490 for the identified section or paragraph, explains the instructions, and contains additional notes to assist specification writers to interpret their applicability.

x.x Model Specification. This element is also drawn from the SD guide, It provides direct illustrations of the MIL-STD-490 format and "boilerplate" requirements statements for each section/paragraph, to which each specification writer may then add statements peculiar to his own system program.

ELECTRONIC SYSTEMS - COMMENT. This element does not always appear. When it does, it consists of comments on selected portions of the system specification which are judged to be of particular interest or importance to computer resources aspects of electronic systems.

SYSTEM SPECIFICATION
CONTENT OUTLINE

1. SCOPE

2. APPLICABLE DOCUMENTS

3. REQUIREMENTS

 3.1 System Definition

  3.1.1 General Description
  3.1.2 Missions
  3.1.3 Threat
  3.1.4 System Diagrams
  3.1.5 Interface Definition
  3.1.6 Government Furnished Property List
  3.1.7 Operational and Organizational Concepts

 3.2 Characteristics

  3.2.1 Performance Characteristics
  3.2.2 Physical Characteristics
  3.2.3 Reliability
  3.2.4 Maintainability
  3.2.5 Availability
  3.2.6 System Effectiveness
  3.2.7 Environmental Conditions
  3.2.8 Nuclear Control Requirements
  3.2.9 Transportability

 3.3 Design and Construction

  3.3.1 Materials, Processes, and Parts
  3.3.2 Electromagnetic Radiation
  3.3.3 Nameplates and Product Marking
  3.3.4 Workmanship
  3.3.5 Interchangeability
  3.3.6 Safety
  3.3.7 Human Performance/Human Engineering
  3.3.8 Computer Programs

 3.4 Documentation

 3.5 Logistics

  3.5.1 Maintenance
  3.5.2 Supply
  3.5.3 Facilities and Facility Equipment

 3.6 Personnel and Training

  3.6.1 Personnel
  3.6.2 Training

 3.7 Functional Area Characteristics

 3.8 Precedence

4. QUALITY ASSURANCE PROVISIONS

 4.1 General

  4.1.1 Responsibility for Tests
  4.1.2 Special Tests and Examinations

 4.2 Quality Conformance Inspections

5. PREPARATION FOR DELIVERY

6. NOTES

10. APPENDIX I

Figure A-1. - Content Outline for the System Specification.

Section 1, SCOPE. As shown in the Model Specification, the first section, SCOPE, starts on page 1 of the specification.

Subsection 1.1, Purpose. The material to be included in this subsection should consist of a clear, concise abstract in one paragraph of the scope and purpose of the coverage of the specification. If desired, a concise statement of the intended application of the specification may also be included.

Subsection 1.2, Classifications. This subsection is included in the event that different classifications of the space system are to be covered by the specification. Because various classifications of space vehicles or other items that might be identified in lower tier specifications are usually all part of the same system, the "Not applicable" entry shown in the Model Specification is usaually correct.

> Note that there are minor differences in 1.1 and 1.2 between Appendix I of MIL-STD-490 and the general requirements for Section 1 given in the body of MIL-STD-490. The guidebook presents a reasonable resolution of the discrepancies.

1. SCOPE

1.1 Purpose. This specification sets forth the requirements for the design, development, manufacture, test, and quality assurance of the (insert nomenclature) space system hereinafter referred to as the system. The requirements covered by this specification are applicable to the (insert nomenclature) system which is a major element of the (insert program identification). These requirements shall be the basis for the preparation of more detailed requirements to be included in:

a. subsequent revisions of the system specification, and in related system documents, such as interface control documents (ICDs);

b. specifications for the system segments and for configuration items (CIs) at lower levels of assembly.

1.2 Classifications. (Not applicable).

Section 2, APPLICABLE DOCUMENTS. As shown in Section 2 of the Model Specification, Governmental documents are listed in subsection 2.1 in numerical order under each of the subheadings shown. Non-governmental documents are listed in subsection 2.2. Non-governmental documents are those not issued by any governmental organization such as documents issued by technical associations, technical societies, commercial organizations, and contractors.

The words, subheadings, and format should be followed with the understanding that subheadings will be omitted if they do not contain applicable documents. A parenthetical source statement should follow each group of related publications indicating the address of the source of the document so that copies may be obtained directly from the source.

All and only those documents identified and referred to in Sections 3, 4, and 5 of the specification, or in mandatory compliance appendices, are listed in Section 2 of the specification. It must be understood that the whole of referenced documents is not made applicable by their inclusion in Section 2. The extent of applicability is only that which is clearly defined, and specifically indicated, at the place it is referenced. The documents listed in Section 2 of the Model Specification are those that are already referenced in the boilerplate requirements of the Model Specification. As other requirements are added during the preparation of a particular system specification, other documents may be referenced and they would also be added in Section 2. Government regulatory documents, such as directives, regulations, manuals, pamphlets, and policies are not usually cited for compliance. These documents are generally intended for internal use by governmental organizations only and are not intended for contractor use. Contractors' internal specifications or documents are not usually cited for compliance because they are typically for internal contractor use and are not readily available to reviewing organizations nor are they so general as to be directly applicable or transferable to a different contractor.

Note that a specific issue, revision letter, and the date of issue is given for each of the referenced documents. The revision letters, amendments, notices, and effective dates shown for the documents listed in the Model Specification may not be current; they will require updating to the date of issue for each specification. Note that amendments to military specifications supersede earlier amendments so only the most recent would be listed. Notices, however, are cumulative and only those notices to be made applicable would be listed. If all "m" notices were applicable, they would be listed as notices "1" through "m" with the date being that for notice "m". Note that the preferred method of stating the date of issue for each document is as the year, month, and day. The year would be given in two digits, the month in three capital letters, and the day in two digits. If a different date format is used, it should be used consistently for all of the documents listed. As the acquisition process moves forward, many of the specific documents referenced may be amended, revised, or superseded. Just because a referenced document may have been updated does not mean that the revision should be referenced. The actual updating of the date of issue for each of the references in the specification, however, must be considered and controlled by the program offices in the same manner as any other changes in the specification.

Note that the preparation of this section deviates in some areas from the requirements in MIL-STD-483 and MIL-STD-490. For example, MIL-STD-490 states that Government regulations and acts of Congress should be referenced in specifications whereas those "internal" document references are no longer acceptable.

2. APPLICABLE DOCUMENTS

2.1 Governmental documents. The following documents of the exact issue shown form a part of this specification to the extent specified herein.

SPECIFICATIONS:

Federal

Military

DOD-E-8983C 77 DEC 29	Electronic Equipment, Aerospace, Extended Space Environment, General Specification for
MIL-M-38310B 74 JUN 15	Mass Properties Control Requirements for Missile and Space Vehicles
DOD-W-8357A 77 DEC 22	Wiring Harness, Space Vehicle, Design and Testing, General Specification for
MIL-S-83576 74 NOV 01	Solar Cell Arrays, Space Vehicle, Design and Testing, General Specification for
DOD-A-83577A 78 MAR 15	Assemblies, Moving Mechanical, for Space Vehicles, General Specification for
DOD-E-83578 79 OCT 01	Explosive Ordnance for Space Vehicles, General Specification for

Program Specifications

(TBS)

Other Government Activity

STANDARDS:

Federal

Military

MIL-STD-1472B 74 DEC 31 Notice 1 76 MAY 10	Human Engineering Design Criteria for Military Systems, Equipment and Facilities
MIL-STD-1522 72 JUL 01	Standard General Requirements for Safe Design and Operation of Pressurized Missile and Space Systems

DRAWINGS: (Where detailed drawings referred to in a specification are listed on an assembly drawing, it is only necessary to list the assembly drawing.)

OTHER PUBLICATIONS:

Manuals

Regulations

Handbooks

MIL-HDBK-5C	Metallic, Materials and Elements for Aerospace Vehicle Structures
MIL-HDBK-17A	Plastics for Flight Vehicles - Part 2, Transparent Glazing Materials

Bulletins

(Copies of specifications, standards, drawings, and publications required by suppliers in connection with specified procurement functions should be obtained from the contracting office or as directed by the contracting officer.)

2.2 Non-governmental documents. The following documents of the exact issue shown form a part of this specification to the extent specified herein.

SPECIFICATIONS:

STANDARDS:

DRAWINGS:

OTHER PUBLICATIONS:

(Technical society and technical association specifications and standards are generally available for reference from librairies. They are also distributed among technical groups and using Federal agencies. The contracting officer should be contacted regarding the availability of any referenced document not readily available from other sources.)

Section 3, REQUIREMENTS. As shown in Section 3 of the Model Specification, the requirements should be stated in terms of performance, reliability, design constraints, functional interfaces, etc. that are necessary to assure a practical and reasonable development effort. The requirements should clearly describe the space system and should include any unique space requirements such as for manufacturing process control of critical items. Note that the major elements of the space system may include ground equipment as well as the space equipment. Requirements that are only applicable to some of the elements should not be stated in ways that would make those requirements applicable to the entire system. Functional statements of the requirements should predominate in system specifications with fabrication details specified only to assure matching interfaces with existing elements. As the acquisition progresses the TBSs and TBDs would be determined and those requirements would be incorporated in the specification and, if appropriate, in lower tier specifications. The major effort in the initial phases of a program is in the allocation of the requirements to lower levels of assembly and the preparation of specifications for the system segments and lower tier CIs.

Referencing military, federal, and DoD adopted industry specifications and standards is the approved method for establishing requirements that are adequately set forth in the referenced documents. Before referencing any document, be sure to read the specific issue of the referenced document to assure the applicability of the requirements. Tailoring the references should be accomplished to limit the extent of applicability of the requirements such as illustrated in the following examples:

a. "The design of electronic components shall be in accordance with DOD-E-8983" would incorporate only the design requirements of DOD-E-8983 for all electronic components covered by the specification (both ground and space). The quality assurance provisions would not be made applicable by such a reference.

b. "The design of the receiver X shall be in accordance with DOD-E-8983" would incorporate only the design requirements of DOD-E-8983 for receiver X, but not for any other possible receivers or applications in the system being specified.

c. "Electronic components for space vehicle applications shall be in accordance with DOD-E-8983" makes all requirements (design and quality assurance) in DOD-E-8983 applicable to the electronic components to be used in space vehicles covered by the specification. Requirements in DOD-E-8983 would not be made applicable to ground components or to aircraft components by such a reference.

As a general rule, program peculiar item specifications external to the system being specified should not be referenced except to identify an interface. Instead, the applicable requirements should be extracted and incorporated in their entirety.

[illegible] Definition. The intent of the material included in this subsection and subtier paragraphs is to clearly define the system that is being specified. As with any definition, the intent is not to state detailed "shall" requirements but to simply describe the system and to identify its major [illegible] elements, its functional areas, and its functional and physical interfaces. Depending upon the amount of system engineering that may have been completed and the complexity of the system being specified, the definition subparagraphs may include: block diagrams; functional diagrams; logic diagrams; schematic diagrams; specification trees; pertinent organizational, operational, and logistic concepts; identification of major system segments; and any other pertinent descriptive material.

These definition paragraphs are particularly important in a space system specification. In fact, in the initial draft of a space system specification, subsection 3.1, Definition, may have only text because defining the system being specified is always the first step for programs control. As the studies, analyses, and system development progress, additional requirements can be stated. Eventually the subtier elements of the system can be identified to provide the framework of standard terminology to be used. By that means all participants can recognize common items, tasks, schedules, costs, interfaces, or other common elements of the system and of the program. Although the primary focus in these paragraphs is on the description of the space system, including its subtier elements, the system interfaces with the rest of the world are also to be identified. These external interface descriptions may involve references to other system specifications, or to documents prepared by other agencies. It is important to recognize the "uncontrolled" nature of these external interface references. For example, a DoD space system specification may describe an interface by referencing a Space Transportation System specification issued by NASA. That reference, however, does not assure that the actual interface is as described or that it will not be changed by NASA at some later time.

In the early phases of a system acquisition, the referencing of higher level specifications or external documents is the only reasonable course to follow in describing the interfaces. As the acquisition progresses, an effort should be made to eliminate these external "uncontrolled" references. This can be accomplished by the preparation and joint approval of interface control documents. The interface control documents could then be referenced in the specification or they could be the basis for the direct incorporation of the definitized interface requirements. Eventually, detailed configuration item (CI) specifications would be prepared for the actual procurement of the various system elements. These CI specifications should be "stand alone" documents and should not reference higher level specifications or externally controlled documents. This practice avoids the possibility of two documents each referencing the other, and each document stating that it takes precedence over the other document.

By including the definition in the requirements section of the specification, contractors and others using the specification can recognize the intent to assure compliance with the space system description given. Although requirements may include definitions, it should be noted that definitions are not an appropriate place to include detailed design or test requirements. This section and the subparagraphs are definitions that are intended to be descriptions of the system to be fulfilled by the detailed design, as opposed to stating "shall" requirements or specifying a precise set of verifiable performance requirements.

As shown in the Model Specification, 3.1, System definition, is usually very brief with most of the required text entirely within subtier paragraphs. Usually a list of functional areas of the system is included and a list of subtier elements of the system is also included in 3.1. These lists are simply for the convenience of those using the specification and are incorporated into the specification when the information becomes available. For example, the prime configuration items are not usually identified precisely until after the system specification has been fully completed. Of course, the lists shown in the Model Specification are typical and should be changed to conform to the particular system being specified.

Paragraph 3.1.1, General description, is the paragraph that contains an expanded description of the system from that given in 3.1 and identifies the functional areas and the relationship of the system being specified to other systems. In that context the program should be briefly described in terms such that all systems or other major elements of the larger program are identified.

Paragraph 3.1.2, Missions, is included to provide a description of operational missions and related information that could affect the design.

Paragraph 3.1.3, Threat, is included to identify potential threats to the system that should be considered in the design so that the system performance would not be jeopordized even if the threat conditions materialized. For space elements it might include nuclear attack, pellet attack, laser attack, electronic jamming, all of the above, or none of the above. For ground elements it might include conventional weapons, sabotage, nuclear, or whatever. The Model Specification takes the easy way out and suggests (Not applicable). Of course, that may not be the correct entry for a specific system.

Paragraph 3.1.4, System diagrams, should incorporate the top level functional flow diagrams. If a top level functional flow diagram for the program is developed it should be incorporated into this paragraph. The program level diagram provides the framework for describing the system being specified, the interfaces with other systems, and for expanding the functional flows to lower levels. In any case, the top-level functional flow diagrams for the system would be incorporated. The system functional flow diagram should be an expansion of the applicable program level functions.

When available, layout drawings or other graphic portrayal which establish the general relationship of functional areas and the major elements of the system should be included.

When the subtier elements of the system have been identified, a specification tree should also be incorporated. A specification tree is a configuration item oriented diagram or chart that shows the allocated CIs that make up the item being specified. The specifications which identify each subitem would be shown on the tree. Other specifications which serve to identify external interfaces including the government-contractor interfaces may also be shown. The specification tree for the entire program should be included, if it is available, to assist in the identification of the system interfaces. In any case, the space system specification tree would be incorporated to identify the system segments and as many of the subtier CIs as possible. This specification tree for the system does not need to be complete, particularly at the lower tier levels, but the CIs that can be identified will provide a framework for correlating the hardware, the statement of work tasks, the work breakdown structure (WBS), the cost reporting requirements, the program scheduling, and the data items required to properly manage the program. The specification tree, or equivalent indentured list of CIs, is needed by all of the program participants as early as possible to serve as a common means of identification of the program elements. If the specification tree is depicted in a separate document or drawing whose size prevents incorporation into the specification, it is referenced by document or drawing number.

3. REQUIREMENTS

3.1 Definition. The space system is an element of the (insert program). The system is subdivided into the following system segments:

a. Space system segment which includes the following identified configuration items: (TBS)

b. Ground terminal system segment which includes the following configuration items: (TBS)

c. Data reduction system segment which includes the following configuration items: (TBS)

3.1.1 General Description. (TBS)

3.1.2 Missions. (TBS)

3.1.3 Threat. (Not applicable)

3.1.4 System Diagrams.

3.1.4.1 Functional Flow Diagrams. The top functional flow diagram for the system is shown in Figure 1. First-level flow diagrams for operational, maintenance, test, and activation functions are shown in Figures 2, 3, 4, and 5. (TBS)

3.1.4.2 Specification Tree. The specification tree for this system is shown in Figure 6.

ELECTRONIC SYSTEMS - COMMENT:

Samples of functional flow block diagrams reproduced from the system specification for a large data processing system are provided in Appendix C of this guidebook.

Paragraph 3.1.5, Interface definitions, may be a heading (title) with subparagraphs, or text may follow the title. The paragraph should identify all functional and physical interfaces that must be considered; however, the interfaces should not be specified as precise inputs, outputs, and dimensions that will require inspection for verification. Usually references are made to the functional diagrams and to the specification tree included in 3.1.4 to help identify the various interfaces.

Interface control drawings and other engineering data may be referenced if helpful to define all functional and physical interfaces required to make the system compatible with other items. Although the details of the interfaces may be stated in these referenced documents, the details should be repeated, by extraction or by reference, in the appropriate subparagraphs such as in 3.2, 3.3, or 3.5 because paragraph 3.1.5 is still part of the definition subsection.

At some point in the development of the system, it will be possible to identify the interfaces between the subtier system segments that are part of the system being specified. Usually the description of these internal interfaces would reference the specification tree for the space system included in 3.1.4. As with the system external interfaces, these internal interfaces are only defined in this paragraph and must be detailed in the 3.7 paragraphs where the system segment characteristics are stated. Where interfaces may differ due to changes in operational mode, they shall be stated in a manner which identifies specific interface requirements with each different mode.

> 3.1.5 Interface definitions. The space system interfaces with other elements of the space program are defined in Figure 7. (TBS)

ELECTRONIC SYSTEMS - COMMENT:

Instructions in MIL-STD-490 require that this paragraph not only *identify* interfaces (a) with other systems and (b) among major parts of this system but that it also provide (either directly or by reference) engineering data to *define* both functional and physical interfaces precisely. This area poses many problems and potential pitfalls for software, in particular:

a. The normal expectation based on aerospace vehicle and other hardware experience is that many of the physical interfaces will be defined late in a system program (typically, "by CDR"), then added to this part of the system specification by reference to ICDs.

b. With very few exceptions, however, precise definitions of all interfaces affecting software should be completed and available for identification in the system specification by the end of a validation phase. ICDs are seldom useful for this purpose (for further discussion of considerations pertaining to software/software and software/hardware interfaces, see ref. 18, para. 3.4).

c. Interface information for a large electronic system is typically extensive. Careful planning is needed to avoid unnecessary redundancy, as well as the frequent errors of inaccuracy and omissions. "Interfaces" are also performance characteristics to be specified in 3.2.1, and further amplified for each system segment in 3.7. Although inconvenient to users, the liberal use of cross-referencing is often preferable to repeating the same precise definitions in multiple locations.

Paragraph 3.1.6, Government furnished property list, usually only consists of a list of the Government furnished property which the system shall be designed to incorporate. This list must identify the property by reference to its nomenclature, specification number, and item number if available. If the list is extensive, it may be included in an appendix or in a separate specification supplement or other document which would then be referenced in this paragraph. The list in the Model Specification is typical and should be changed to conform to the particular system. Specific quantitites, including spares, should be indicated. If there is Government property that is essential to the system development that can be loaned for that purpose, it should be listed separately in this paragraph. Government property which can be made available to support the system and can be loaned to the contractor might include computers, software, tools, and trailers. Often the correct entry under the "For loan" heading is (Not applicable). The schedule of availability and associated costs, if any, for the use of Government-loaned property should not be stated in the specification.

3.1.6 Government furnished property list.

3.1.6.1 For incorporation. The following GFP shall be incorporated into the system as indicated:

a. COMSEC equipment (TBS)

b. Rocket motors (TBS)

c. Explosive ordnance (TBS)

d. Payload equipment (TBS)

e. Propellants (TBS)

3.1.6.2 For loan. The following Government property may be loaned for use in developing the system: (TBS)

Paragraph 3.1.7, Operational and organizational concepts, is usually included in a system specification to provide operational information that could help define the system and that could affect the design such as:

a. The basic performance parameters upon which the using activities can base tactics which utilize the capabilities of the system and which should be recognized in the design.

b. Description of the mission in terms of relationships to other items of the system or to other systems.

c. Anticipated deployment of the system equipments, both geographically and organizationally, such as the number of operational vehicles, number of ground support installations and their operating locations.

Note that the Model Specification provides general words for a space system where the space vehicle is launched using either the Space Transportation System (STS) or is launched using an expandable launch vehicle. The requirements should of course be worded to reflect the actual operational concept. In addition, any organizational concepts that could affect the design should be included in added paragraphs.

3.1.7 Operational and organizational concepts. The system supports a space vehicle launch and possible retrieval using the Space Transportation System (STS) or for launch using the (TBS) expandable launch vehicle. On-orbit operations are planned to be controlled from the mission control center (MCC) located (TBS) and remote tracking stations (TBS).

3.1.7.1 STS operational concept. The following STS operational concept is supplied as a guide for use in the system design and for the preparation of operational plans and test plans:

3.1.7.1.1 STS prelaunch. The space vehicle would be transported from storage or directly to the launch base where final space vehicle preparations and checkout would be accomplished at the Payload Preparation Room of the STS launch facility. Final intersegment and launch verification tests would be accomplished after space vehicle and associated equipment installation in the STS and prior to launch.

3.1.7.1.2 STS launch. During STS ascent to the parking orbit, various space vehicle subsystems or system equipments may be powered on or turned off in order to provide protection from the STS environments or to comply with STS safety requirements. Space vehicle telemetry to monitor vehicle status would be provided to the STS for monitoring and retransmission (in real time or playback) to the ground monitoring stations.

3.1.7.1.3 STS parking orbit operations. While the space vehicle is attached to the STS, vehicle telemetry to monitor vehicle status continues to be provided to the STS for monitoring and retransmission (in real time or playback) to the ground. When the space vehicle is released from the STS, responsibility for monitoring and control would be transferred to the ground mission control center (MCC). The STS may provide assistance for the resolution of anomalies when requested by the MCC. In the event of unsatisfactory deployment or unsatisfactory space vehicle checkout, the STS would retrieve the vehicle and return to the launch site.

3.1.7.1.4 Space vehicle orbit injection. After release by the STS and successful vehicle checkout and appendage deployment, the vehicle would boost itself (or would be boosted) into its operational orbit under command from the ground.

3.1.7.2 Expendable launch vehicle operational concept. When the use of an expendable launch vehicle is planned, the following operational concept is the guide for use in the system design and for the preparation of operational plans and test plans: (TBS)

3.1.7.2.1 Prelaunch. The space vehicle would be transported from storage or directly to the launch base where final vehicle preparations and checkout would be accomplished on the launch vehicle after mating. Final intersegment and launch system verification tests are accomplished prior to launch.

3.1.7.2.2 Launch and injection. During launch and injection to the operational orbit, the various vehicle subsystems may be powered on or turned off in order to provide protection from the launch and injection environments or to comply with other specified requirements. Space vehicle telemetry to monitor vehicle status would be provided during launch and

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3.7.3.3 Mission completion. At the completion of the space vehicle mission, the space vehicle would be either deboosted to the STS retrieval orbit, de-orbited, or all equipment would be commanded off. For STS retrieval, the space vehicle provides space vehicle safety status and other required verification data to the STS. Once captured, the space vehicle would be stored in the STS payload bay. In the event of an unsuccessful STS retrieval, the space vehicle would be de-orbited. At the appropriate point in the orbit the STS would de-orbit and return to VAFB. After STS rollout and safing, the STS would be brought to the STS Processing Facility where the space vehicle would be removed and processed for transportation to the factory. Also, in the event of an aborted STS launch, it would be at this point that the space vehicle would be recycled back to the launch pad or to the factory. (Where mission completion consists of command all equipment off, that should be specified instead of retrieval or de-orbit. Where it is planned that a space vehicle launched using an expendable launch vehicle may be retrieved or serviced using the STS, specific on-orbit or mission completion requirements would be described.)

Subsection 3.2, Characteristics. This subsection generally starts with a title heading for the paragraphs that follow. The intent of the material included in this subsection is to clearly state in quantitative terms the pertinent performance requirements and physical characteristics of the system. Requirements that are applicable to a system segment or to a single prime CI, such as the space vehicle, should be stated in the appropriate paragraph in subsection 3.7 and not in this subsection.

Paragraph 3.2.1, Performance characteristics, includes general and detail requirements, under appropriate subheadings, for all performance requirements, i.e., what is expected of the system including both the range of values and tolerances. Again note that the combined performance of the entire system, or at least that of two or more of the system segments, are addressed in this paragraph and the subparagraphs. The performance of a single system segment or of an individual CI would be addressed in subsection 3.7. Other subparagraphs for other performance characteristics may be added in this subsection depending upon the system. Other typical headings may include deployment, instrumentation, design commonality, and reference timelines.

Paragraph 3.2.1.1, Operational phases and modes, identifies each of the operational phases and modes. Phases may include launch, on-orbit, ground operations, reentry, and recovery although there may be other phases that could be appropriate to a particular system such as: (a) surveillance, (b) threat evaluation, (c) target designation and acquisition, (d) weapon deployment, and (e) data reduction. Modes may include various configurations, power levels, or other differences that may occur during one of the phases that requires special design attention.

Paragraph 3.2.1.2, Dynamic, states the system dynamic performance parameters required for each phase and mode.

Paragraph 3.2.1.3, Endurance, states the quantitative criteria covering endurance capabilities of the system required to meet user needs under stipulated environmental and other conditions, including minimum total life expectancy. The required mission duration and planned utilization rate in the various modes should be indicated. The endurance requirements stated in the Model Specification are typical and should be changed to the times and requirements of the specific system.

3.2 Characteristics.

3.2.1 Performance.

3.2.1.1 Operational Times and Modes. (TBS)

3.2.1.2 Dynamic. (TBS)

3.2.1.3 Endurance. The ground based elements of the system shall have a design service life of 20 years. The elements of the system associated with the STS Orbiter operations shall have a design service life of 15 years. The on-orbit design life of the space vehicle, as may be limited by mechanical wearout, battery life, solar array life, or the exhaustion of expendables, shall be no less than five years. The design of the space vehicle shall be such that space vehicle storage, under controlled conditions, may be planned for as long as four years. The design service life of the space vehicle shall be ten years based on the sum of the allowed storage time, pre-launch checkout time, launch and injection time, on-orbit time, recovery time, and contingency time. (TBS)

3.2.1.4 Other. (TBS)

ELECTRONIC SYSTEMS - COMMENT

Note that the performance requirements to be specified here are those which pertain to the system as a whole, or are common to two or more segments. These are later apportioned to each system segment (in subsection 3.7), normally by reference to this paragraph, together with additional requirements peculiar to the individual segments. Jointly, the performance requirements set forth here and in 3.7 constitute the *principal content of the system specification as a whole as it pertains to requirements for system software*. These are the requirements upon which development (Type B5) specifications for CPCIs will be based. The information should normally be extensive, in that it should provide a definitive translation of operational, organizational, and support concepts described in the preceding paragraph 3.1 into a complete set of implementing, data processing operations.

All system functions required to perform the mission described previously in paragraph 3.1 are to be identified. A subparagraph should be devoted to each function which specifies required performance associated with the function in terms of capacities, loads/volumes of data, reaction times, accuracies, and other relevant characteristics. The proper "level" at which these requirements should be specified varies with the system and particular function being specified. Generally, the objective is to define required system capabilities comprehensively, but at the same time to avoid details which can be amplified later within the intended scope. As an example:

> "Each intercept direction center shall be capable of scrambling interceptors from up to 6 airbases. ... Guidance commands shall be computer-generated and displayed to weapons team personnel to permit voice control of manned interceptors on (types of missions, types of interceptors, number of interceptors controlled, frequency of computed commands, handling of aborted missions, etc.) ... When interceptors follow the commands, the following accuracies shall be achieved at least 87% of the time: The difference between actual and specified crossing angle at rollout shall be less than 15 degrees; The intercept rollout point shall be within 4.5 miles of the desired rollout point; ..."

Such requirements, at the system level, are adequate to dictate the scope and nature of amplifying detail which will then have to be developed for documentation in the Type B5 specification for a CPCI. The latter must "fill in" extensive data to define, for example: quantitative flight characteristics of each specified interceptor type, together with tracking and other essential inputs to the command computations; mathematical formulas (not algorithms) for the computations, including timing and accuracies; types of operating, alarm, and other controller displays, together with detailed formats and contents as a function of operating mode, intercept phase, and contingencies.

Paragraph 3.2.2, Physical characteristics, sets forth physical requirements in the appropriate subheadings that are applicable to two or more of the system segments. Physical characteristics include such items as weight limits and dimensional limits necessary to assure physical compatibility with other program elements and not determined by other design and construction features or referenced drawings. The paragraphs may also include considerations such as tie down requirements for transportation, security criteria, durability factors, health and safety criteria, survivability, and vulnerability factors. The physical characteristic requirements of a single system segment or of individual CIs would be addressed in subsection 3.7 of the specification. Additional subparagraphs may be provided depending on the system.

Paragraph 3.2.2.1, Mass properties, states requirements for limiting and controlling the mass properties of the system elements. Usually general requirements are stated for space elements such as the space vehicle, the space vehicle support equipment for use in the STS orbiter, and for the payload. In addition, general mass property requirements for fixed and mobile ground equipment is usually stated to avoid excessive floor or road loading or to allow transportability.

Paragraph 3.2.2.2, Dimensions, identifies the coordinate systems used in the system and any envelope constraints imposed on the system.

Paragraph 3.2.2.3, Power, states the requirements both for external electrical power to be supplied to the various elements of the system and for power to be generated by the various elements of the system and supplied to other items. Care should be taken to distinguish between power supplied to, and power being supplied from, each of the system items during each of the operating modes.

Paragraph 3.3.3.4, Durability, is a general motherhood requirement intended to indicate the degree of ruggedness required.

Paragraph 3.2.2.5, Survivability, is where requirements would be stated for consideration of atomic, chemical, biological, radiological, fire, and impact vulnerability and survivability.

3.2.2 <u>Physical characteristics</u>

3.2.2.1 <u>Mass properties</u>. The mass properties of the space elements shall be determined in accordance with MIL-M-38310. The weight of the space vehicle shall not exceed (TBS). The weight of the space elements shall be controlled for the preservation of performance margins and as a control of other mass properties. The recommended weight contingency for space elements is as follows:

a.	Preliminary design	- new equipment	20 per cent
		GFE & existing equipment	5 per cent
b.	Critical design	- new equipment	10 per cent
		GFE & existing equipment	3 per cent
c.	Final design	- new equipment	5 per cent
		GFE & existing equipment	2 per cent

The mass properties of ground elements of the system shall be consistent with their intended application. The weight of hand carried equipment shall not exceed 10 kilograms (kg). The center of gravity of ground equipment shall be such that probable seismic activity will not cause the equipment to upset. The weight of ground elements shall be controlled to avoid excessive floor loading for fixed equipment and excessive road loading for mobile equipment. The weight of all equipment shall allow transportability by truck and C-5 aircraft.

3.2.2.2 Dimensions. The coordinate definitions and envelope constraints for the system shall be as shown in Figure 3. For the spaceborne elements, the envelope constraints shall be based upon the dynamic envelopes encountered during factory assembly, system test, transportation, integration with the booster, launch, and other phases of operations.

3.2.2.3 Power. The primary electrical power on the space vehicle shall be in accordance with MIL-STD-1539. The primary electrical power supplied to the system equipment mounted in the STS Orbiter shall be (TBS). The primary electrical power supplied to the ground based elements of the system shall be (TBS).

3.2.2.4 Durability. The system equipment shall be so designed and constructed that no fixed part or assembly shall become loose, no movable part or assembly shall become undesirably free or sluggish, and no degradation shall be caused in the performance beyond that specified for the system equipment during operation or after storage.

Paragraph 3.2.3, Reliability, and the subparagraphs state requirements for the reliability of the system to perform within specified limits for the service life of the system. Other subparagraphs may be added to cover areas other than MTBF and redundancy.

Paragraph 3.2.3.1, Mean time between failures, is where MTBF requirements are stated for the system. The "boilerplate" in the Model Specification is typical, but should be changed for each program.

Paragraph 3.2.3.2, Redundancy, is a typical general statement of redundancy requirements for all elements of a space system. Specific requirements may be added, or changes to the "boilerplate" may be made based upon the system requirements.

Paragraph 3.2.4, Maintainability, specifies the quantitative maintainability requirements in the planned maintenance and support environments. The requirements may include such items as:

a. Time values for mean and maximum down time, for mean times between maintenance actions, for mean and maximum times to repair, for reaction times, and for turnaround times.

b. Rate values indicating frequency of preventative maintenance, for maintenance man hours per specific maintenance action.

c. Maintenance complexity including numbers of people, skill levels, and variety of support equipment.

d. Maintenance action indices including maintenance costs per operating hour and man hours per overhaul.

Note that contractor maintenance is generally applicable to space systems and that the same maintainability requirements are not usually applicable to all elements of the system.

3.2.3 Reliability. The reliability allocations shall assure that the overall mission reliability requirements are met under the most severe extremes of storage, transportation, testing, and operations. To the extent practicable, the system design shall be such that a failure in one component shall not propagate to other devices or components. Where practicable, the space vehicle shall be capable of detecting malfunctions while in orbit and automatically initiating protective measures to avoid catastrophic loss of the space vehicle.

3.2.3.1 Mean time between failures. The mean time between failures for the elements of the system shall be analytically determined for each operating mode. Piece part or component failure rates obtained from actual usage data shall be used where available. Failure rates estimated from standard data sources evaluated at anticipated operating conditions shall be used when data under actual usage is nonexistent or inadequate. The system reliability shall be evaluated in terms of events and usage cycles that occur during a typical service life cycle.

The space vehicle probability of survival curve shall be represented by its equivalent Weibull function:

$$R(t) = e^{[-(t/\alpha)^{\beta}]}$$

where α = scale parameter
β = shape parameter

The space vehicle probability of survival for the nominal service life shall be at least 0.5 assuming the probability of launch success to be at least 0.98. The space vehicle probability of survival shall include consideration of any potential failures in associated ground operations, such as commanding, that might not be corrected in time to avoid an impact on the space vehicle.

3.2.3.2 Redundancy. Redundancy to eliminate single point failure modes may be incorporated to meet the reliability requirements, unless the addition of redundancy actually reduces overall reliability due to the added complexity. For designs that switch redundant units, components, or subassemblies autonomously, or by command, the failure rates for the switching circuits, and for the redundant equipment while in the off-line mode, shall be appropriately included in the reliability determination. Where practicable, provisions shall be incorporated to verify the operation of all switchable redundant paths without disassembly.

3.2.4 Maintainability. To the extent practicable, the spaceborne elements of the system shall be designed so as not to require any scheduled maintenance or repair during their service life. Where practicable, the design of space elements shall incorporate test and telemetry points to allow verification of functional performance and shall accommodate easy installation and replacement of major subassemblies. The ground based elements shall be designed with self test features. The ground based elements shall be designed using modular construction for ease of maintenance to assure the equipment availability required to achieve the specified service life and mission reliability.

Paragraph 3.2.5, Availability, states the availability requirements that may include availability for on-orbit operations, for launch readiness, and for recovery. Availability is the degree to which the system must be in an operable and committable state at the start of a mission where the mission is called for at an unknown or random point in time. When the STS is used, there are limitations imposed, particularly during the prelaunch and launch sequence, on access or availability of the system space equipment for test or maintenance activities. When applicable, these limitations should be stated in this paragraph because of their possible impact on the space equipment design and on the design and location requirements for ground support equipment.

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Paragraph 3.2.6 System effectiveness, is marked (Not applicable) because there is not a consensus as to what it means. If there are requirements relating to system effectiveness that are not covered in other paragraphs, they should be included in this paragraph.

Paragraph 3.2.7, Environmental conditions, and the subparagraphs provide for statements of the various environmental levels for the system during the various operating phases. If environmental levels are specified, they should be the design levels that include the desired margins. Where various levels are possible during a phase, the environmental levels specified should be a composite that covers the maximum and minimum values. If the use of composite values is not appropriate, a further subdivision should be used to make the necessary distinction in design levels for the various configurations or categories. If the system segments are different from each other, the environmental conditions would be addressed only in 3.7. This paragraph would then state "(see 3.7)".

Paragraph 3.2.7.1, Launch environments, is intended to present the design environmental requirements for all system items that undergo launch. This would be specified as the STS payload environment for STS launches, the launch environment inside the nose fairing for an expendable booster if that is appropriate, or it would be a composite of both launch modes.

Paragraph 3.2.7.2, On-orbit environments, states the design environmental requirements for orbiting elements of the space system. This could include separation from the STS, injection, various on-orbit modes, and recapture by the STS as may be appropriate for the particular program.

Paragraph 3.2.7.3, Ground environments, specifies the design environmental requirements for the various elements of the space system that are intended for ground installation and use. However, note that the orbiting elements of the space system also have a ground environment prior to launch and possibly after return from orbit. If any of the handling, transportation, or other ground environments for any of the orbiting elements exceed the design values specified for launch or on-orbit, then those ground environments should be specified. Either added environmental protection could then be developed for ground operations or the ground environments would be considered in the design of the orbiting elements.

Paragraph 3.2.7.4, Other environments, is intended to specify the design environmental requirements for the various elements of the space system during other applicable phases not covered by launch, on-orbit, or ground, such as reentry or crash.

3.2.5 Availability. (TBS)

3.2.6 System effectiveness. (Not applicable)

3.2.7 Environmental conditions. To provide a design factor of safety or margin, the various system CIs and their components shall be designed to function during, or if appropriate following, exposure to environmental levels that exceed, by the specified margins, the maximum levels predicted for all applicable operational modes during the service life of the CIs. Unless otherwise specified, the maximum predicted environments for the spaceborne equipment shall be determined in accordance with the definitions in MIL-STD-1540. Where practicable, each space component shall be designed to operate continuously within an ambient temperature range of at least -34 deg C to +71 deg C and at ambient pressures between sea level and deep space.

3.2.7.1 Launch environments. The space elements shall be designed to function within performance specifications after, or if appropriate during, exposure in the launch configuration to environmental levels that exceed the maximum predicted launch environments by the design factor of safety or design margin.

3.2.7.2 On-orbit environment. The space elements shall be designed to function within performance specifications following, or if appropriate during, exposure in the on-orbit configuration to environmental levels that exceed the maximum predicted on-orbit environemnts by the design factor of safety or design margin.

3.2.7.3 Ground environments. These environments are those associated with all operations of ground equipment and the operation on the ground of the space equipment, including storage, transportation, and prelaunch operations. The system CIs shall be designed to function within performance specifications following, or if appropriate during, exposure in the ground configuration to environmental levels that exceed the maximum predicted ground environments by the design factor of safety or design margin.

Paragraph 3.2.8, Nuclear control requirements, states the general boilerplate requirements for controlling nuclear material. These requirements may include component design, in-flight controls, and safety-related requirements.

Paragraph 3.2.9, Transportability, states the requirements for system transportability. Make sure the last sentence in the boilerplate is consistent with the ground environmental provisions specified in 3.2.7.3.

Subsection 3.3, Design and construction. This subsection generally starts with a title heading for the paragraphs that follow. The intent of the paragraphs included in this subsection is to clearly state design and construction requirements and constraints that may be applicable to the system as a whole or to more than one system segment. Design or construction requirements that are applicable to a single system segment or to a single CI should be stated in 3.7, not here.

Paragraph 3.3.1, Parts, materials, and processes, and the subparagraphs are general boilerplate requirements for the system. Deletions or additions should be made where appropriate to satisfy the requirements for a particular system. If the paragraphs are not applicable they should be so marked. Note that the management task of establishing a parts, materials, and processes control program is not included in the specification, but would be stated as a task in the SOW when it is a formal requirement.

Paragraph 3.3.2, Electromagnetic compatibility, states the general requirements for EMC. If there are tempest requirements imposed on the system they would be stated also.

Paragraph 3.3.4, Workmanship, states the general workmanship requirements including the workmanship requirements for development models or prototypes to be produced during the system development.

Paragraph 3.3.5, Interchangeability, specifies the requirements for the level at which components shall be interchangeable or replaceable. Entries in this paragraph are for the purpose of establishing a condition of design, and are not to define the conditions of interchangeability that are required by the assignment of a part number.

Paragraph 3.3.6, Safety, states the safety design requirements for avoiding hazards to personnel and equipment. Safety related requirements applicable to a single functional area should not be addressed in this paragraph, but would be stated with the requirements for the functional area (in 3.7). Note that the management task of establishing a safety program based upon an approved safety plan is not included in the specification. If the management of a safety program is desired, it would be stated as a task in the SOW and approval of the safety plan would be required by an appropriate entry on the CDRL.

Paragraph 3.3.7, Human performance/human engineering, states general boilerplate requirements for accommodating man-equipment interactions. This paragraph should also specify any special or unique requirements such as any constraints on allocation of functions to personnel and verbal communications. Specific areas, stations, or equipment that require concentrated human engineering attention to avoid critical human errors should be identified.

Paragraph 3.3.8, Computer programming, states general requirements applicable to computer programs to be developed as elements of the system. These may include use of standard programming languages, objectives for modular design, and other design characteristics considered essential to minimize program errors or facilitate their later operational use and support.

3.3 Design and construction

3.3.1 Parts, materials, and processes. Unless otherwise specified in the contract, the parts, materials, and processes shall be selected and controlled in accordance with contractor established and documented procedures to satisfy the specified requirements. The selection and control procedures shall emphasize quality and reliability to meet the mission requirements and to minimize total life cycle cost for the system. An additional objective in the selection of parts, materials, and processes shall be to maximize commonality and minimize the variety of parts, related tools, and test equipment required to fabricate, install, and maintain the system. However, identical electrical connectors, identical fittings, or other identical parts shall not be used where inadvertent interchange of items or connectors could cause possible malfunction.

3.3.1.1 Structural materials. Materials shall be corrosion resistant, or shall be suitably treated to resist corrosion when subjected to the specified environments. Structural properties of materials for use in space applications shall be taken from MIL-HDBK 5 for metals and from MIL-HDBK-17, Parts 1 and 2, for plastics. Properties not listed shall be based upon material tests. (TBS)

3.3.1.2 Finishes. The finishes used on system CIs and their components shall be resistant to corrosion. There shall be no destructive corrosion when exposed to moderately corrosive environments such as industrial environments or sea coast fog. Destructive corrosion shall be construed as being any type of corrosion which interferes with meeting the specified performance of the device or its parts.

3.3.1.3 Material Selection. Materials shall be selected that have demonstrated their suitability for the intended application. Materials used shall be resistant to fungus. Use shall not be made of combustible materials or materials that can generate toxic products of combustion. Protection of dissimilar metal combinations shall be in accordance with MIL-STD-889.

3.3.2 Electromagnetic radiation. The system shall be designed in accordance with MIL-STD-1541. Tempest requirements are (TBS).

3.3.3 Nameplates and product marking. The system CIs and each interchangeable subassembly shall be identified by a nameplate. The nameplate identification may be attached to, etched in, or marked directly on the item. Metal stamping shall not be used. Nameplates shall contain, as a minimum, the following identifications:

a. Item or CI number
b. Serial number
c. Lot or contract number
d. Manufacturer
e. Nomenclature

When size limitations, cost, or other considerations preclude marking all applicable information on an item, the nameplate may simply provide a reference key to cards or documents where the omitted nameplate information may be found.

3.3.4 Workmanship. Equipment shall be manufactured, processed, tested, and handled such that the finished items are of sufficient quality to ensure reliable operation, safety, and service life. The items shall be free of defects that would interfere with operational use, such as excessive scratches, nicks, burrs, loose materials, contamination, and corrosion.

3.3.5 Interchangeability. The design of ground equipment shall provide for modular replacement of components to expedite maintenance and repair. The design of space elements shall provide for factory replacement of components and for pre-launch installation or replacement of explosive ordnance devices, batteries, and major space vehicle components.

3.3.6 Safety. The system shall be designed to minimize safety hazards to personnel and surrounding equipment during installation, maintenance, ground test, transportation, and operational use. The safety requirements and procedures shall comply with all local, state, and federal requirements as well as Range Safety manuals.

3.3.7 Human performance/human engineering. Newly designed equipment shall be in conformance with MIL-H-46855 and MIL-STD-1472, observing principles and criteria set forth in AFSC Design Handbook 1-3.

3.3.8 Computer programming. Computer programs newly developed for this program shall be designed and structured in such a way that functional requirements and computer program components may be modified, added, or deleted without requiring extensive restructuring and recoding of other components. Programming languages shall be used as specified in 3.7.x. ... (TBS)

ELECTRONIC SYSTEMS - COMMENT

Although the system specification is primarily a performance-oriented document, subsection 3.3 provides a place for specifying those *minimum* design/construction requirements which are identified as being essential to effective Air Force use or support of the system. Specification writers have the obligation to assure that such requirements are: necessary, in fact; consistent with estimated program schedules and costs; and also fully compatible with basic performance requirements set forth in other parts of the specification.

It happens that paragraph 3.3.8 is the only part of a system specification for which instructions contained in either MIL-STD-490 or MIL STD-483 make explicit mention of computer programs. Possibly due to that fact, there has been a noticeable tendency to overemphasize its importance both as a part of this subsection and in relation to other areas of system requirements (e.g., see preceding comment on paragraph 3.2.1). One system specification was issued in 1979--admittedly, a "worst case"--in which 3.3.8 alone occupied *12% of the* *page space in the entire specification!* However, it is clear that needs exist for better guidance in this area than has yet been formulated for general use. Appendix B of this guidebook contains a sample of one approach which has been proposed, together with further comments on associated questions and problems.

Subsection 3.4, Documentation. This subsection is where general documentation requirements should be specified. It should be noted that no requirements for the delivery of documents or data may be included in this paragraph, nor elsewhere in the specification. Data or documents to be delivered for review or approval must be listed in the CDRL and referenced in the contract. The requirements included in this paragraph should outline the general plan for engineering drawings, specifications, technical manuals and other types of documentation required to support design reviews, manufacturing, testing, operations, maintenance, and logistic support.

> 3.4 Documentation. Only documentation listed in the Contract Data Requirements List (CDRL) shall be formally delivered for review or approval. It is intended, however, that during the course of the system acquisition process appropriate results of trade studies, analyses, and development efforts will be internally documented to support design decisions and scheduled technical reviews. The final system documentation shall be such that subsequent production items can be produced that are equivalent in all respects to those tested or delivered. This final documentation shall also be adequate to allow the rapid incorporation of changes when necessary. Operational procedures manuals shall include contingency procedures to minimize the impact of possible anomalies.

ELECTRONIC SYSTEMS - COMMENT

It is normally advisable to include in this paragraph requirements for computer program documentation which will tend to enforce conformance with policies set forth in AFR 800-14. Examples of statements to be considered are:

"All computer programs developed as a part of this system program shall be specified in accordance with the format and content instructions of MIL-STD-483 (USAF), Appendix VI."

"Computer program specifications, manuals, handbooks, test, and version description documents shall be maintained for the life of each CPCI to reflect all Class I and Class II changes, and the responsible computer program developer or support activity shall issue periodic reports to enable verification of their status, in accordance with Appendix VIII of MIL-STD-483."

Such statements function as requirements to be observed, not directly by contractors, but by Program Office personnel responsible for the preparation of contract SOWs and CDRLs.

Subsection 3.5, Logistics. This subsection states the logistic requirements which constrain the system design. The allocation of the program level logistic requirements to the system and to lower tier levels is generally based on minimizing the program and system life cycle costs. Production quantitites, maintenance, and refurbishment opportunities for space systems are extremely limited when compared with other military equipment. This factor usually dictates that the contractor be assigned responsibilities for logistic support for the life of the system. Nevertheless, there may be requirements that should be stated here to assist the contractor in the design.

Paragraph 3.5.1, Maintenance, would typically address such items as: (a) the extent of maintenance to be accomplished at specified locations such as at the launch site, on-orbit, at the landing site, at operating sites, at the depot if one is to be used, or at the factory; (b) test, maintenance, repair, and refurbishment time lines; (c) use of multipurpose test equipment; and (d) the use of module vs. part replacement.

Paragraph 3.5.2, Supply, would address such items as: (a) supply or resupply methods; (b) special storage requirements for parts or items; (c) introduction of new parts or items into the supply system; and (d) distribution and location of item stocks.

Paragraph 3.5.3, Facilities and facility equipment, would address the impact, if any, on existing facilities and facility equipment or any requirements for new facilities or ancillary equipment to support the system logistics. The facility and facility equipment requirements would eventually be transferred to separate facility specifications or other appropriate documents to support their procurement. Generally facility procurements and space system equipment procurements are entirely separate contracts.

> 3.5 Logistics. Equipment designs shall be based upon minimizing the system life cycle cost assuming the contractors provide the logistic support for the system for its service life.
>
> 3.5.1 Maintenance. (TBS)
>
> 3.5.2 Supply. (TBS)
>
> 3.5.3 Facilities and facility equipment. (TBS)

ELECTRONIC SYSTEMS - COMMENT

The standard breakdown of this subsection into paragraphs for maintenance, supply, facilities and facility equipment does not clearly provide for computer program support, but that topic should be covered. A recommended approach is to: (a) use the three standard paragraphs, as intended, for equipment and facilities only; (b) add a fourth paragraph entitled "Computer Program Support"; and (c) insert a sentence into the basic paragraph 3.5 calling attention to this organization. Requirements addressed in the additional paragraph (3.5.4) should include identification of the responsible support center (e.g., NCPC, Sacramento ALC, or other, following the initial period of contractor support), and identification of support functions to be provided at the operating site(s).

In formulating requirements in the context of this topic (logistics), specification writers should be aware that "maintenance" is basically a misnomer for a computer program support activity, which typically devotes the bulk of its allocated time and effort to making *modifications*. Most of those modifications may be minor and relatively routine; however, every "fix" to a CPCI is a design change, which implies that planning in this area must be closely linked with planning for system/software configuration management (see AFR 800-14, Chapter 6, Section C).

Subsection 3.6, Personnel and training. This subparagraph generally starts with a title heading for the paragraphs that follow. For space systems, most personnel and training requirements are usually determined by the contractors. If it is intended that military personnel will operate or maintain the system equipment, it is important that the required number of personnel at each of the available skill levels be identified. For contractor operation or maintenance it would be appropriate to describe in general terms the educational background, experience, or other qualifications desirable for personnel selected to be trained to operate and maintain the system. Care should be taken to avoid overly restrictive personnel requirements because they can impose costly constraints on the equipment design and on other areas of the program such as requirements for spares. The training paragraph could address such requirements as:

a. The concept of how training should be accomplished, e.g., school, unit, or contractor training.

b. The need for simulators, training aids, or other training equipment or devices.

c. The expected training time and locations available for training programs.

Subsection 3.7, Functional area characteristics. This subsection generally starts with a title heading for the paragraphs that follow. A paragraph would be established to address each of the system segments of the system that were identified in 3.1 of the specification. The requirements in these paragraphs may be stated by simply referencing the applicable system segment specifications if they exist. For the space system, the system segment requirements may be so extensive that it may be desirable to simply prepare the space system segment specification at the same time the space system specification is prepared. In that case, the space system segment specifications will detail the system performance characteristics, physical characteristics, special requirements, and interface characteristics allocated to each functional area/system segment, following the full range of format/content conventions which apply to the system specification itself.

3.6 Personnel and training.

3.6.1 Personnel. (TBS)

3.6.2 Training. (TBS)

3.7 Functional area characteristics.

3.7.1 Space system segment. (TBS)

3.7.2 Ground terminal system segment. (TBS)

3.7.3 Data reduction system segment. (TBS)

Subsection 3.8, Precedence. Paragraphs in the Model Specification are typical boilerplate for a system specification. They address (a) precedence as it refers to potential conflicts with other, referenced documents, and (b) orders of priority for requirements stated in the system specification:

Paragraph 3.8.1, Conflicts, states considerations in resolving conflicts that may occur with referenced documents. The general rule is that requirements stated in a given document take precedence over conflicting requirements of referenced documents. In the case of other system specifications, or documents prepared by other agencies, it is especially important that conflicts be identified and resolved. The purpose of boilerplate words in the Model Specification is to assure that conflicts with those other documents be made known and directed to the Contracting Officer for resolution.

Paragraph 3.8.2, Requirements weighting factors, states the relative importance of requirements stated within the specification, since those may not be equal. Relative weights might be assigned to requirements in different areas, such as interfaces, performance, or physical characteristics. The relative weighting of individual factors by the manner in which they are stated, although common practice, should be stated here if it is used. The suggested four levels may be expanded, reduced, or not used at all in a given specification. Note that these factors are appropriate only during early phases of a program; they should not appear in product specifications intended to support a production contract.

3.8 Precedence.

3.8.1 Conflicts. In the event of conflict between the documents referenced herein and the contents of this specification, the contents of this specification shall be considered the superseding requirements, except when a conflict involves interface requirements external to this system. In the event of conflicts involving external interfaces, the order of precedence shall be as directed by the Contracting Officer.

3.8.2 Requirements weighting factors. Compliance with requirements stated within this specification shall be governed by the following factors:

a. "Shall" designates the most important weighting level. Compliance with these requirements is mandatory.

b. "Shall, where practicable" permits alternative designs, items or practice to be used when the use of the alternative is substantiated by documented technical trade studies. These trade studies shall be made available for review or provided to the Government in accordance with the contract provisions. Deviations from these requirements do not require formal approval by the Contracting Officer.

c. "Preferred" or "should" designates requirements from which deviations do not require either documented technical substantiation nor Contracting Officer approval.

d. "May" requirements are stated as examples of acceptable designs, items, and practices. Unless required by other contract provisions, deviations from these requirements do not require technical substantiation nor Contracting Officer approval.

APPENDIX B. SAMPLE PARAGRAPH 3.3.8

Paragraph 3.3.8 is a part of the system specification which is not mentioned in MIL-STD-490 but is called out for Air Force use in MIL-STD-483 (USAF), Appendix III (para. 30.5). Its function is to provide a place in the system specification to specify requirements for computer programs that are comparable to the types of design and construction standards specified in other parts of paragraph 3.3 as a whole for items of system equipment. It happens to be a part of the system specification which has received widespread attention and emphasis in the past few years; and the resulting technical requirements contained in various system specifications have tended to meet with almost-equally widespread controversy.

One sample of specification requirements for this paragraph which has been proposed for general use is reproduced below. It is presented here as an illustration, not as a recommendation. The sample is followed, in this appendix, by a few additional comments pertaining to its merits and shortcomings from the point of view of acquisition management practices.

> This general sample contains minimum essential requirements and is intended to serve as guidance for composing a System "A" Specification Section 3.3.8.
>
> 3.3.8 Computer Programming. Computer programs and computer data bases shall be considered as software. Software shall be categorized as support software or applications.
>
> 3.3.8.1 General Requirements. Software shall meet the following design, language, and coding requirements:
>
> 3.3.8.1.1 Design Requirements
>
> 3.3.8.1.1.1 Computer Program Structure. The computer program structure shall consist of Computer Program Configuration Item(s), Computer Program Component(s), and Module(s).
>
> a. Computer Program Configuration Item (CPCI). A CPCI is the actual computer program end item in the form of computer instructions stored on machine-readable media. A CPCI shall consist of one or more computer program components.

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b. Computer Program Component (CPC). A CPC is a functionally, logically distinct part of a CPCI. A CPC is identified for purposes of convenience in specifying and developing a CPCI as an assembly of subordinate elements. A CPC consists of a logical composition of one or more subordinate or interfacing modules.

c. Module. A module performs a complete logical process by execution of a set of instructions which have clearly defined inputs, processing logic, and outputs. A module is the smallest set of executable statements able to be assembled or compiled. Each module shall conform to the following conventions:

(1) A module shall consist of a set of instructions in a form consistent with the appropriate language, OS, and computer.

(2) A module shall not exceed 100 lines of executable source code. This limitation excludes comments and data definitions.

(3) A module shall have only one entry statement and one exit statement.

3.3.8.1.1.2 Top Down Design (TDD). Software developed under this contract shall be designed in a top down manner. The processing activities of the system shall be identified and organized beginning with higher levels of organization, expanded and broken out to include a more detailed definition of the processing activities by identification of subordinate levels. The lowest level of processing shall correspond to the module.

3.3.8.1.1.3 Top Down Implementation (TDI)

The project software shall be implemented in a top down manner as defined herein. Conceptually, top down implementation proceeds from a single starting point while conventional implementation proceeds from as many starting points as programs in the design. The single starting point does not imply that the implementation must proceed down the hierarchy in parallel. Some branches intentionally will be developed earlier than other branches. For example, user or other external interfaces might be implemented before some of the other partitions to permit early demonstration of software subsystem capabilities, partial software system evaluation, training, or even incremental software system acceptance. The project software shall be implemented in a series of RELEASES which shall provide for successive system capabilities.

3.3.8.1.2 Programming Languages. Software developed for this system shall be restricted to one or more of the following languages:

a. FORTRAN as per ANSI STD X 3.10 - 1966

b. FORTRAN as per ANSI STD X 3.9 - 1978

c. JOVIAL J3 as per MIL STD 1588

d. JOVIAL J73 as per MIL STD 1589A

e. COBOL as per FIPS PUB 21-1

f. IEEE ATLAS Spec. 416A-1978

3.3.8.1.3 Coding Requirements.

3.3.8.1.3.1 Commenting Standards. Software developed under this contract shall adhere to the following commenting standards:

3.3.8.1.3.1.1 Banners. A banner shall be a block of comments which appears once at the beginning of each module. A banner shall visually break the project software into units of codes corresponding to the CPCI decomposition (module level). Banners shall have an identical format for each module within a CPC. The banner shall enclose the following information: CPCI title, CPIN, CPC title, and CPC number. The banner shall occur once in each module listing, immediately preceding the header.

3.3.8.1.3.1.2 Headers. Headers shall consist of a block of consecutive comments arranged to facilitate the understanding and readability of each module. This form of block commenting shall be used in lieu of individual comments being scattered throughout a module. Headers shall occur once at the beginning of each module and shall conform to the standards described herein. The observer shall be able to read the MODULE-HEADER and understand the processing activities of the module without having to read program code. The minimum required MODULE-HEADER comments are described below. These comments shall appear in the form and in the order illustrated below:

MODULE-HEADER COMMENTS

MODULE-NAME - Followed by a one-line functional description.

ABSTRACT - The ABSTRACT shall be a set of consecutive comments which describe the module's purpose, use, and processing activities. Elaboration on the technical aspects of the algorithms should be avoided where references to external Government documentation would suffice. The ABSTRACT should paraphrase the activities of the code in English terms. References made to external Government owned documentation shall be listed in the REFERENCES comment section.

REFERENCES - NO-1, TITLE, DATE (YY/MM/DD)
NO-2, etc.

INPUTS - Variables, Tables (local, system), files, and other data input sources shall be identified separately as to type, unit of measure, size, limits and ranges of unit of measure, accuracy or precision requirements, frequency of arrival.

OUTPUTS - Variables, Tables (local, system), Files and other data output sources shall be identified in the same manner as inputs.

PROGRAMS CALLED - Names of other programs called followed by brief abstract of purpose and pre and post conditions of each call.

LIMITATIONS - Description of any constraints upon the execution of the program. For instance, conditions which would alter the logical operation of the program or cause the results of the program's computations to be altered.

MODIFICATIONS - NO-1, MOD description, DATE (YY/MM/DD)
NO-2, etc.

3.3.8.1.3.1.3 Special Comments. Wherever code is particularly subtle or confusing, SPECIAL-COMMENTS shall precede the statement(s) to describe the activities of the subject code. SPECIAL-COMMENTS are provided only to aid the observer in reading program code and are not intended to replace MODULE-HEADER comments.

3.3.8.1.3.2 Structured Coding. Computer programs coded for the system shall employ only the control constructs listed below. These constructs shall be built using logically equivalent language simulations. Instructions in the language used shall follow the graphic representations in Figure 1.

a. SEQUENCE. Sequence of two or more operations.

b. IF-THEN-ELSE. Conditional branch to one of two mutually exclusive operations and continue.

c. DO-WHILE. Operation repeated while a condition is true. Test is before operation.

d. CASE. Select one of many possible cases.

3.3.8.2 Operating System (OS) Requirements. The OS shall conform to the following requirements:

a. The OS shall be a vendor-supplied, off-the-shelf package.

b. OS augmentations shall be allowed but shall be limited to the design of new software. No augmentations shall be permitted to be embedded within the vendor supplied OS software.

c. For all augmentations, contractor developed software shall be developed to interface the vendor-supplied OS for all OS augmentations.

d. No OS interface or augmentation software shall compromise the capability of the OS vendor to provide maintenance over the life cycle of the systems.

e. No instructions shall be executed that will cause the computer to halt processing pending an external event, except by the OS. An exception to this restriction shall be permitted for augmentations to the OS where the augmentation is designed as an extension of the processing control of the OS. The exception is subject to review and approval by the Government.

3.3.8.3 Firmware Requirements. Computer programs and data loaded in a class of memory that cannot be dynamically modified by the computer during processing shall be considered firmware. Requirements on firmware shall be the same as those on software. Use of firmware shall be subject to approval by the Government.

3.3.8.4 Software Utility Services. This support software shall provide the following minimum capabilities:

a. Compilation.

b. Assembly which produces relocatable object code.

c. Linking type loader.

d. Generation, maintenance, and initialization of storage media for programs and data.

e. Diagnostics to support fault isolation.

f. Editing and debugging tools.

3.3.8.5 Message Generation. The generation of error/diagnostic messages shall make a distinction between (1) the requirements for on-line messages to facilitate real-time fault isolation required to maintain the system in operational status and (2) the logging of fault messages onto system files for the category of faults which require isolation and correction but can be addressed off-line and do not degrade the system performance. The required processing time to identify and generate an error/diagnostic message either for on-line or off-line isolation and correction shall not degrade the operational requirements of the system.

a. Processor message and advisory formats shall not require additional interpretation by the operator, such as table lookups and references to documentation, with the exception of lengthy diagnostic procedures to be followed by the operator following an abnormal condition.

b. No computer program shall generate a message or advisory identical to one generated by the OS or by another program.

c. Off-line error messages shall contain as a minimum the following information:

(1) Time error was detected.

(2) Textual description of error condition.

(3) Required operator action where applicable.

(4) Contents of instruction register and program counter at time of error.

(5) Identification of triggering module.

(6) Computer program or system execution status following the error.

On-line error messages shall contain as a minimum the information in items (1), (2), and (3) above.

3.3.8.6 Program Coding Conventions. Software developed under this contract shall conform to required coding conventions stated below.

a. Each line of source code shall contain no more than one statement.

b. Source code shall be clearly and conspicuously annotated to explain all inputs, outputs, branches, and other items not implicit in the code itself.

c. Names of operator commands, data entries, program components, variables, procedures, and other software components shall be consistent with those used in system design.

d. Code shall be written such that no code is modified during execution.

3.3.8.7 Character Set Standards. Character sets shall conform to standards in FIPS-1 Standard Code for Information Interchange, ANSI-X3.4-1968.

Note: Figure 1, Control Constructs
is maintained at ESD/TOIS
AV/478-2701

The following comments represent opinions of this author, based on considerations pertaining to the suitability of the proposed sample for its intended function as a part of the system specification. Technical merits of the material, as such, are not addressed here, although it should perhaps be noted that various portions of the content have met with both some agreement and some disagreement among technical reviewers.

Overall, only some portions of the requirements set forth in this sample are truly appropriate to intended and actual functions of paragraph 3.3.8 in the system specification. Roughly half of the material does illustrate a form and *type* of material which is in accordance with accepted specification practices, while the other half appears to have been formulated for other purposes. Further work is needed to "separate the wheat from the chaff", and to better reflect the system acquisition/contracting implications of requirements stated in a system specification. More specifically:

a. Portions of the material which do constitute requirements suitable for this paragraph are those specifying characteristics of the computer program design and coding--i.e., as contained in subparagraphs: 3.3.8.1.1.2, Top Down Design; 3.3.8.1.2, Programming Languages; and 3.3.8.1.3.2, Structured Coding. When specified in 3.3.8, it must be assumed that the requirements are intended to apply to all developmental CPCIs in all system segments; otherwise, they should be specified in paragraph 3.7 or in the Type B5 (Part I) specifications for individual CPCIs.

b. The sample as a whole is at odds with the significant principles that design and construction requirements should (1) be held to a minimum and (2) make maximum use of references to existing standards. Its extensive coverage and detail suggest that this sample is written more as a vehicle for disseminating a variety of proposed general computer programming standards than as a serious model of content for the system specification as such. That impression stems somewhat from repeated appearance of the phrase, "...under this contract" (3.3.8.1.1.2, 3.3.8.1.3.1, 3.3.8.6)--a phrase which should be reserved for some other type of document--as well as from the questionable emphasis devoted to requirements in such areas as the following:

(1) Paragraph 3.3.8.1.1.3, Top Down Implementation (TDI). These are requirements for contractor internal procedures, not for CPCI design and construction. As such, they represent a level of requirements which should normally be avoided altogether, in either specifications or contract statements of work. Such procedures are best left for the contractor to propose voluntarily, e.g., as a part of his computer program development and/or quality assurance plans.

(2) Paragraphs 3.3.8.1.3 through 3.3.8.1.3.1.3. These are requirements, not for design and construction as such, but for contractor-deliverable information *about* the design and construction. Such requirements have no function in the system specification. They will yield the desired results only if expressed specifically in each contract, *in the CDRL*, and properly coordinated with backup instructions provided therein for (a) delivery and content of the CPCI product specification (DI-E-3120A) and (b) delivery of the CPCI itself (DI-E-30145).

(3) Paragraphs 3.3.8.4 and 3.3.8.5. These are requirements, again not for design and construction, but for system functional capabilities, which should be determined for each system and spelled out elsewhere in the body of the system specification--notably, in paragraph 3.2 and appropriate subparagraphs under 3.7.

(4) Paragraph 3.3.8.6, Program Coding Conventions. This paragraph seems to consist of a mixture of "afterthoughts":

- Subparagraph (b) is subject to the comment (2) above.
- Subparagraph (c) is a tautology.
- Subparagraph (d): The phrase, "...such that no code is modified during execution" appears to be loosely worded; as written, it covers coded data values as well as computer instructions.

APPENDIX C. SAMPLE FUNCTIONAL FLOW BLOCK DIAGRAMS

This appendix provides a few examples of functional flow block diagrams (FFBDs), illustrating one prominent form of system engineering documentation which should normally be contained, or referenced, in paragraph 3.1.4 of a system specification.

The following figures, C-1 through C-6, are drawn from a system segment specification prepared for the Data Systems Modernization (DSM) Program, reference 16. The complete set of FFBDs contained in that source consisted of 116 diagrams covering top-level through fourth- (and in some cases, fifth-) levels, for twelve major functions. The samples reproduced here are selected to illustrate: (a) the one, top-level FFBD for the segment; and (b) one each of the first- through fourth-level diagrams.

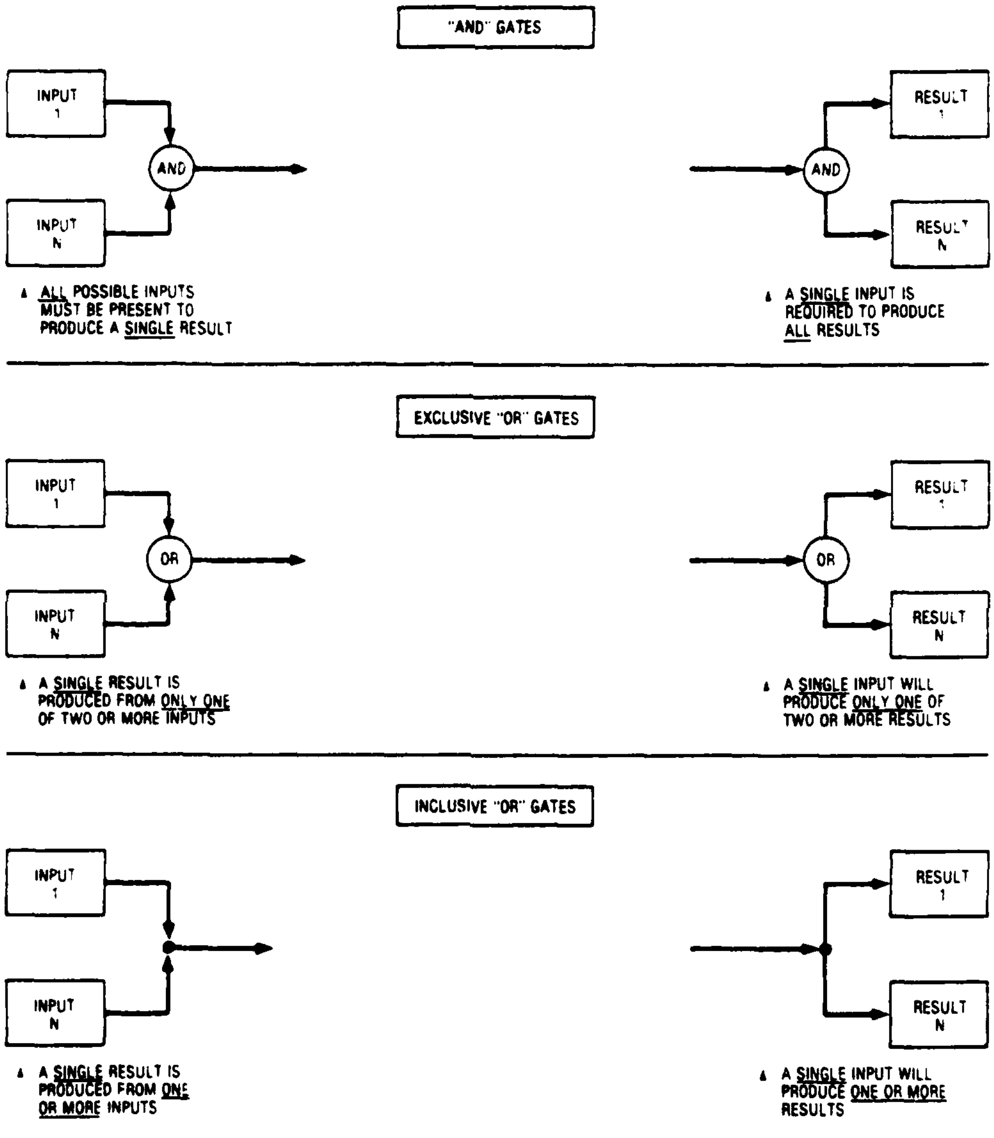
Figure C-1 illustrates specific logic notations used in constructing these FFBDs. General rules and format for the diagrams are based on instructions contained in DI-S-3604.

NOTES:

a. Functions shown in parallel may interact, although interconnecting lines are not provided to denote those interactions.

b. These diagrams show only the flow of functions/subfunctions required to carry out the system mission. Associated narrative definitions, data content, and performance requirements derived in the course of generating the FFBDs are documented in other sections and paragraphs of the system specification.

c. The diagrams reproduced here are selected to illustrate one vertical "thread" within the total FFBD hierarchy--i.e., each lower-level diagram expands one function shown in the preceding diagram. Arrows are added, in these figures, to identify the successively-expanded functions.



NOTE: IN THE USE OF PARALLEL FUNCTIONS, TWO OR MORE FUNCTIONS MAY BE PERFORMED CONCURRENTLY AND MAY INTERACT.

Figure C-1. Logic Notations.

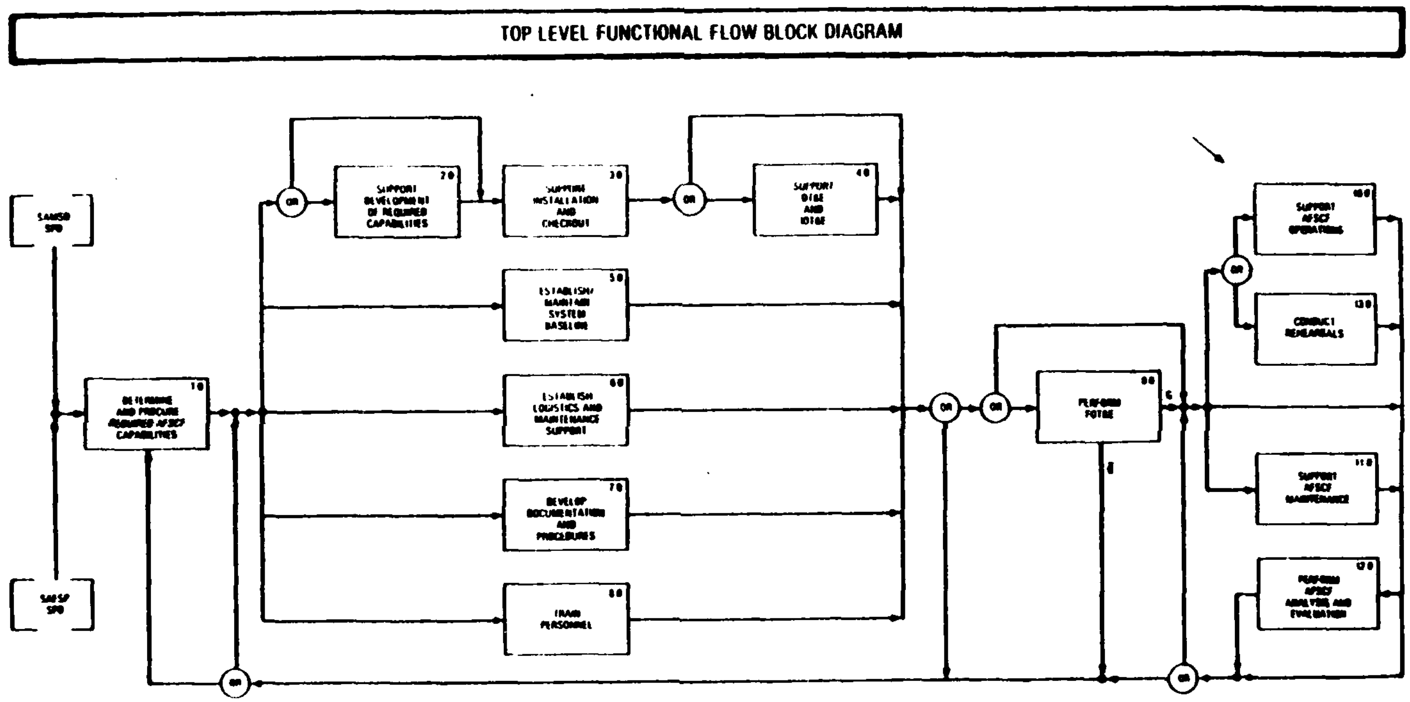


Figure C-2. Top-Level Functional Flow Block Diagram.

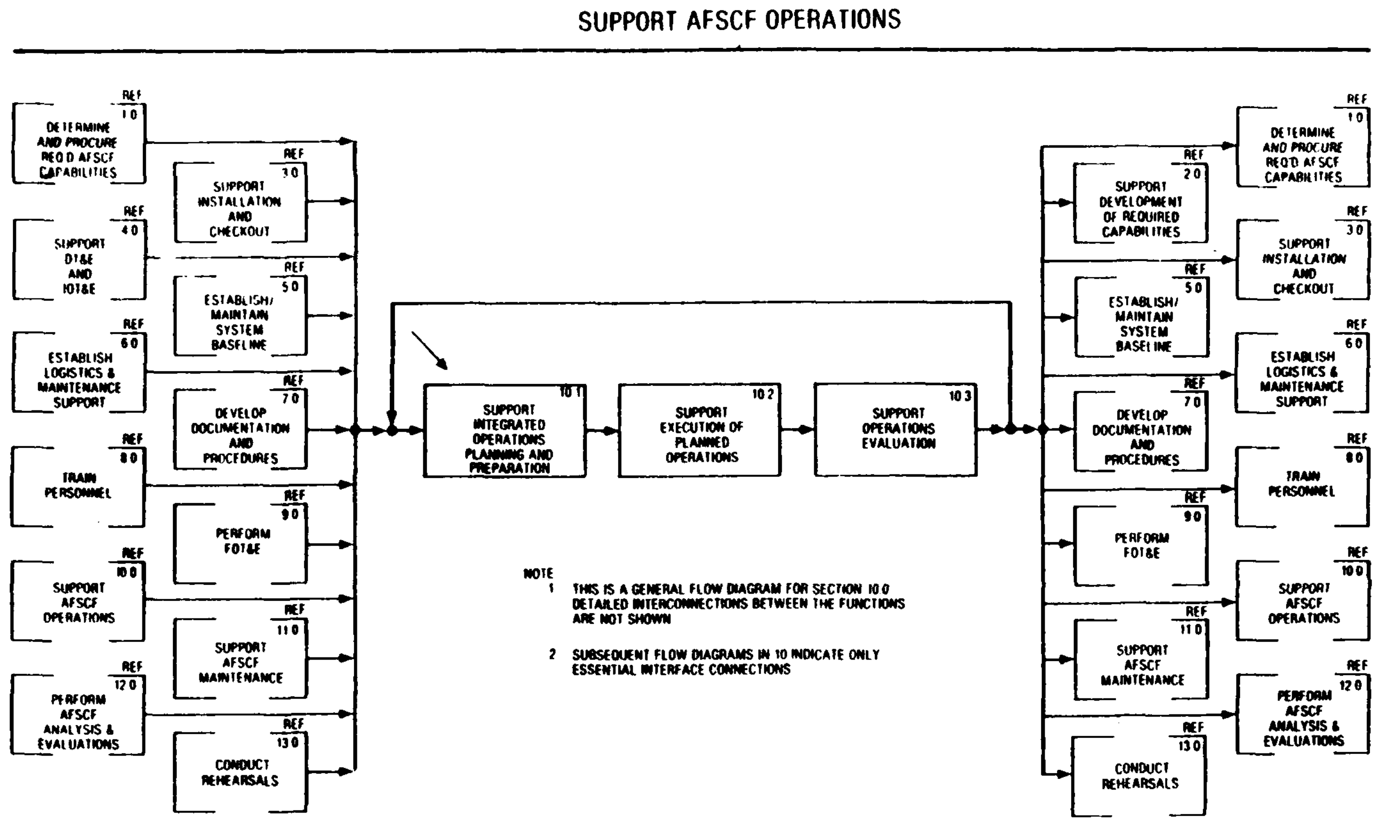


Figure C-3. First-Level Functional Flow Block Diagram.

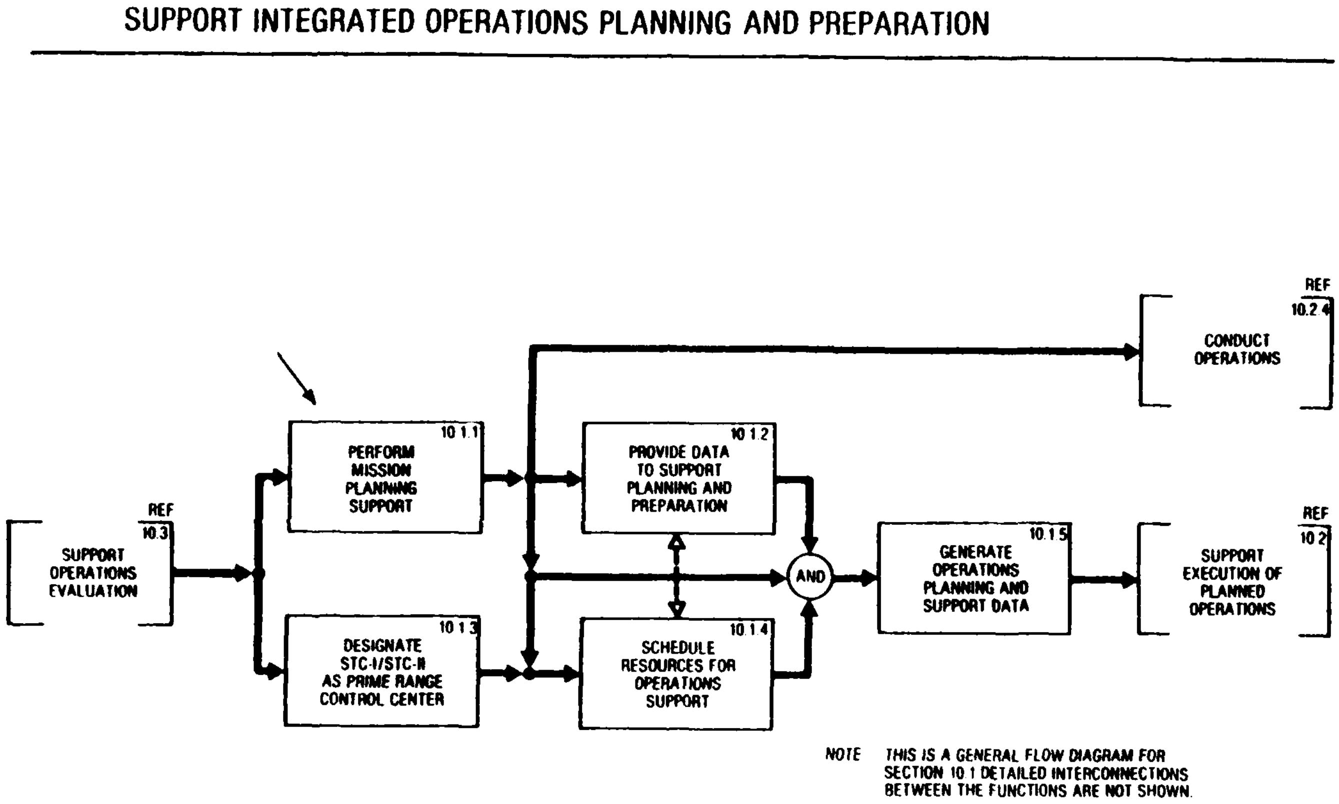


Figure C-4. Second-Level Functional Flow Block Diagram.

PERFORM MISSION PLANNING SUPPORT

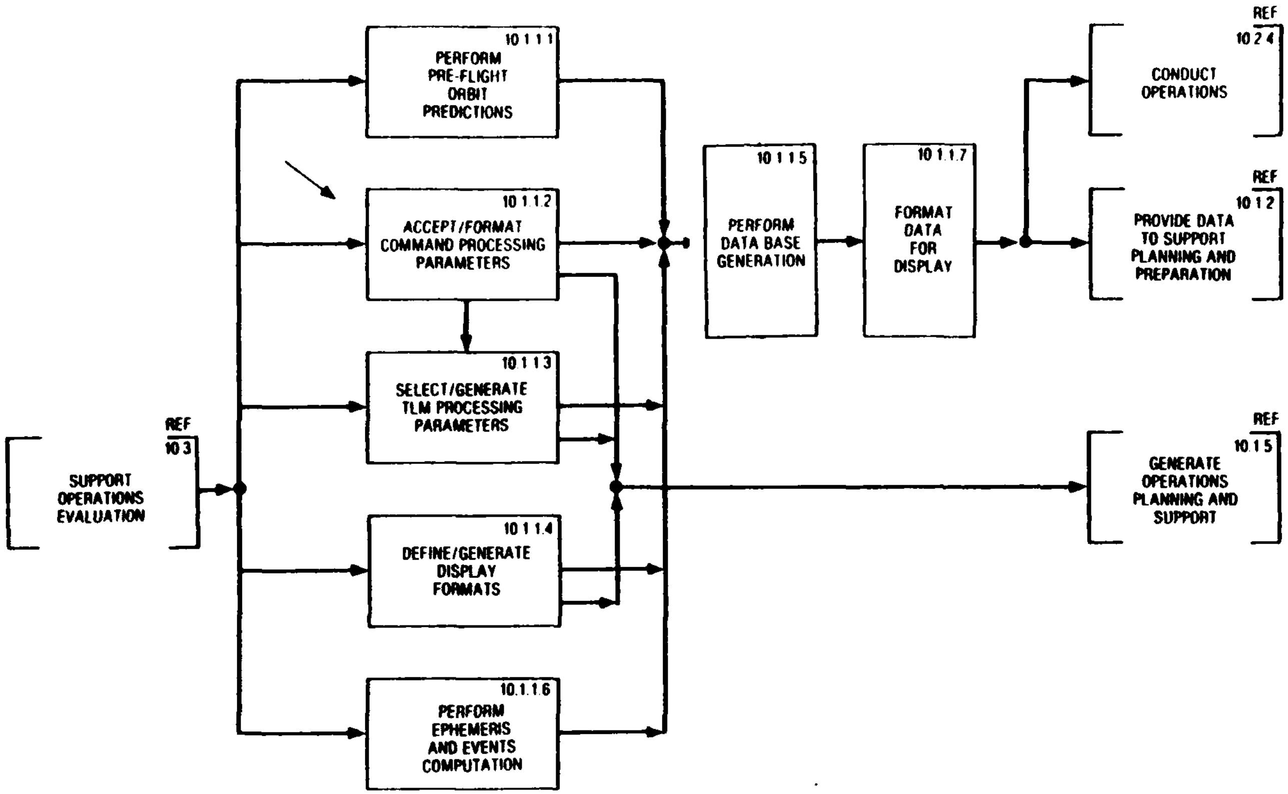


Figure C-5. Third-Level Functional Flow Block Diagram.

RECEIVE/FORMAT COMMAND PROCESSING PARAMETERS

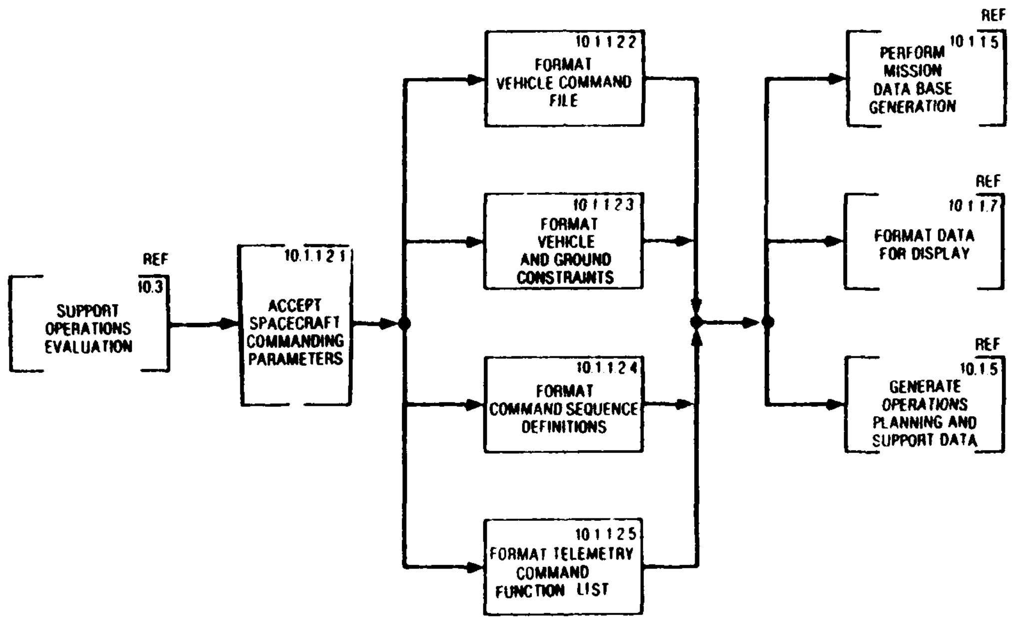


Figure C-6. Fourth-Level Functional Flow Block Diagram.

APPENDIX D. REFERENCES

(1) AFR 57-1, Statement of Operational Need (SON). 12 June 1979.

(2) AFR 800-14, Volume II, Acquisition and Support Procedures for Computer Resources in Systems. 26 September 1975.

(3) AFSCP 800-3, A Guide for Program Management. 9 April 1976.

(4) AFSCP 800-6, Statement of Work Preparation Guide. 18 August 1972.

(5) AFSCP 800-7, Configuration Management. 1 December 1977.

(6) MIL-STD-483 (USAF), Configuration Management Practices for Systems, Equipment, and Computer Programs. 12 April 1971. Notice 2, 21 March 1979.

(7) MIL-STD-490, Specification Practices. 30 October 1968.

(8) MIL-STD-1521A (USAF), Technical Reviews and Audits for Systems, Equipment, and Computer Programs. 1 June 1976.

(9) MIL-S-83490, Specifications, Types and Forms. 30 October 1968.

(10) DI-S-3604, Functional Flow Block Diagrams. 1 November 1971.

(11) DI-S-3605, Requirements Allocation Sheets. November 1971.

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(13) DI-S-3607, Schematic Block Diagrams. 1 November 1971.

(14) DI-E-3120A, Computer Program Product Specification. 17 April 1972.

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(17) DoD Weapons System Software Management Study. Johns Hopkins University, Applied Physics Laboratory. APL/JHU SR75-3, June 1975.

(18) Searle, L. V., An Air Force Guide to the Computer Program Development Specification. ESD-TR-78-139, Electronic Systems Division, AFSC, Hanscom AFB, Massachusetts. March 1978. (NTIS Accession No. AD-A055573).

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APPENDIX E. ABBREVIATIONS

AFCC	Air Force Communications Command
AFDAP	Air Force Designated Acquisition Program
AFLC	Air Force Logistics Command
AFSC	Air Force Systems Command
AFR	Air Force Regulation
ALC	Air Logistics Center
ATC	Air Training Command
CCB	Configuration Control Board
CDR	Critical Design Review
CDRL	Contract Data Requirements List
CI	Configuration Item
CPCI	Computer Program Configuration Item
CPDP	Computer Program Development Plan
CRISP	Computer Resources Integrated Support Plan
D&F	Determination and Findings
DoD	Department of Defense
DSM	Data Systems Modernization
DT&E	Development Test and Evaluation
ECP	Engineering Change Proposal
ESD	Electronic Systems Division
FFBD	Functional Flow Block Diagram
HQ USAF	Headquarters United States Air Force
ICD	Interface Control Document
MENS	Mission Element Need Statement
NCPC	NORAD Computer Programming Center
PCA	Physical Configuration Audit
PMD	Program Management Directive
PMP	Program Management Plan
PO	Program Office
QQPRI	Qualitative and Quantitative Personnel Requirements Information
RAS	Requirements Allocation Sheet
RFP	Request For Proposal
SAM	Software Acquisition Management
SCN	Specification Change Notice
SD	Space Division
SDR	System Design Review
SEMP	System Engineering Management Plan
SON	Statement of Operational Need
SOW	Statement of Work
SRR	System Requirements Review
TBD	To Be Determined
TBS	To Be Supplied
TEMP	Test and Evaluation Master Plan
WBS	Work Breakdown Structure

END

DATE

FILMED

10-81

DTIC